This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

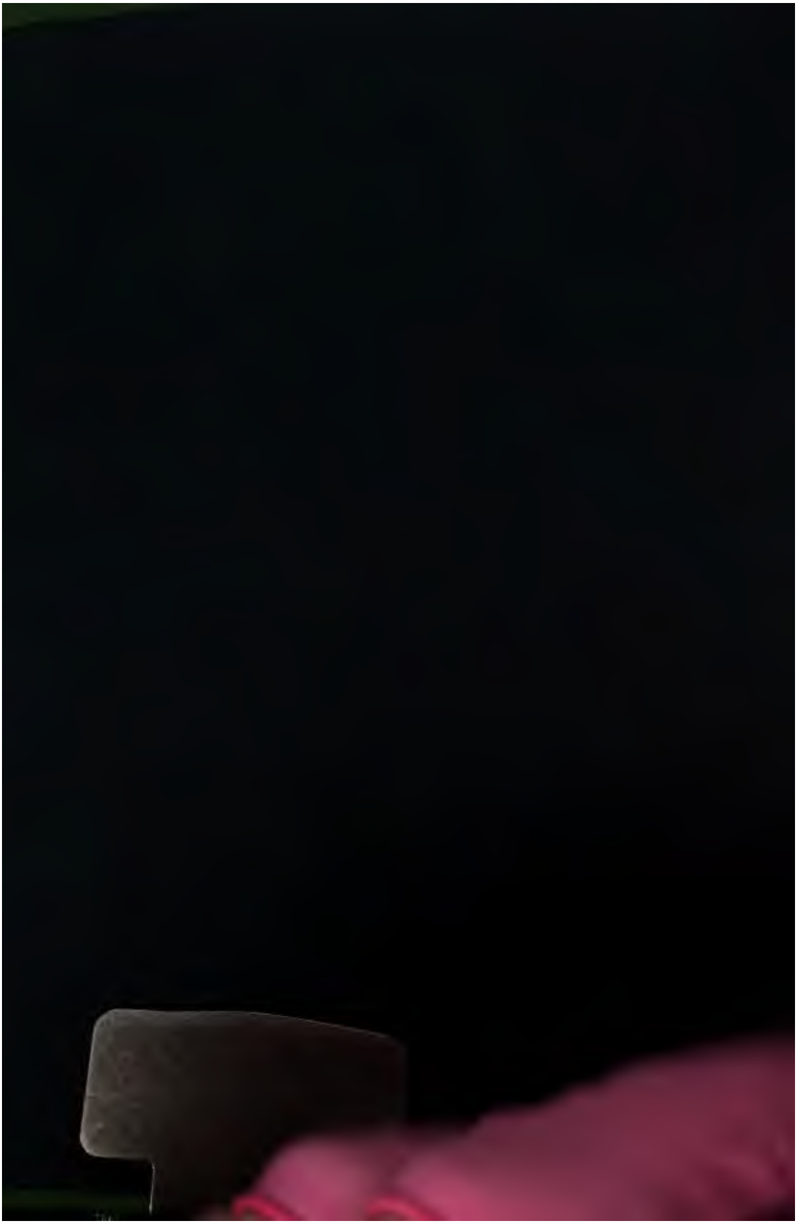
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`



Just published, in fcap. 8vo. Price 4s. 6d.

A NEW EDITION OF

JUKES'S

L MANUAL OF GEOLOGY.

ED BY ALFRED J. JUKES-BROWNE,

of St. John's College, Cambridge.

rated with Numerous Wood Engravings.

Just published, in fcap. 8vo. Price 4s. 6d.

A NEW EDITION OF

JUKES'S

SCHOOL MANUAL OF GEOLOGY.

EDITED BY ALFRED J. JUKES-BROWNE,

of St. John's College, Cambridge.

Illustrated with Numerous Wood Engravings.

ELEMENTS OF ZOOLOGY.

ELEMENTS

OF

ZOOLOGY

For the use of Schools and Science Classes

BY ANDREW WILSON

LECTURER ON ZOOLOGY, EDINBURGH

ILLUSTRATED

BIBLIOTHECA · BODLEIANA ·

EDINBURGH : ADAM AND CHARLES BLACK
1873

189. g. 119.

Printed by R. & R. CLARK, *Edinburgh*.

TO

GEO. J. ALLMAN, M.D.

F.R.S. ETC.

LATE REGIUS PROFESSOR OF NATURAL HISTORY IN THE
UNIVERSITY OF EDINBURGH,

THIS WORK,

ON A DEPARTMENT OF SCIENCE

TO WHICH HE HAS MADE SO MANY AND

IMPORTANT CONTRIBUTIONS,

AND IN ACKNOWLEDGMENT OF MUCH KINDNESS,

IS RESPECTFULLY DEDICATED

BY HIS QUONDAM PUPIL

THE AUTHOR.

PREFACE.

As a lecturer on Natural History, and more especially to junior students, the Author, before commencing the task of writing a Manual of Zoology, had long felt the want of a suitable text-book to supplement the information given in his courses of lectures. When his work therefore was begun, the Author had no choice between recommending to his pupils books of a ponderous and highly technical nature, or those, on the other hand, which, from their popular character, were equally unsuited for the purposes of scientific instruction.

In the production of the present work, the Author has accordingly endeavoured to preserve a medium course; and, whilst treating the subject after a strictly scientific fashion, he has also sought to blend such explanation as would be manifestly required and looked for in an elementary treatise. He would therefore hope that the present Manual may be found serviceable to those who, like himself, are engaged in the every-day tuition of science; a labour, by the way, which is now beginning to be duly appreciated as an essential part of a liberal educational programme.

With regard to the mode in which the various departments of the subject have been treated, little will require to be said in the present instance. The theoretical matter which inevitably meets one on the threshold of biological science, has been but lightly touched upon; whilst in the equally difficult subject of classification, the Author has thought it better to follow in the footsteps of his elders and mentors in the science, than to seek new roads and paths for himself. The most recent classifications have been very generally adopted, but the Author has not hesitated to retain an older system where simplicity, consistent with accuracy, could be obtained. Both Series of the Animal Kingdom have been similarly and fully dealt with; the knowledge of the higher and Vertebrate forms being, in the Author's opinion, equally desirable and interesting with that of the Invertebrate groups.

The great majority of the illustrations have been drawn on wood by the Author, and engraved under his personal superintendence. Some few diagrammatic woodcuts are original; others appear here for the first time; several have, through the kindness of the publishers, been adapted from Professor Owen's Palæontology; whilst, in nearly every case, the authorities from which illustrations have been culled are duly acknowledged. The figures illustrating the classification of the Birds, and also the examples of the Mammalia, have been drawn from specimens in the British Museum and elsewhere, by Mr. W. H. Rickatson of London, to whom the Author would here acknowledge his sense of obligation, and tender his thanks for the service thus rendered him.

For the better explanation of that bugbear of scientific study—technical terminology—a Glossary, compiled from various sources, has been added to the work.

In conclusion, the Author has to acknowledge the assistance he has derived from the works of Owen, Huxley, Allman, and others, whose views he has thought fit to state, without tying himself to the acceptance or advocacy of their opinions. He has, lastly, to thank those friends from whom, in the progress of the work through the press, he has received much assistance; and to offer the excuse of every busy and occupied life, in mitigation of the delay in the appearance of his book.

EDINBURGH, *November* 1872.

CONTENTS.

PART I.—INTRODUCTORY MATTER.

CHAPTER I.

Divisions of Natural Science—Differences between Organic and Inorganic Bodies—Life and Organisation—Differences between Animals and Plants . . . . Pages 1-9

CHAPTER II.

Divisions of Biological Science—Morphology, Physiology, and Distribution—Specialisation of Function—Morphological Types—Homology and Analogy—Symmetry of Animal Forms—Classification 10-28

PART II.—INVERTEBRATE ANIMALS.

CHAPTER III.

Protozoa—General Characters of Protozoa—Classification—Gregarinida—Rhizopoda—Spongida—Infusoria—Tabular Classification of Protozoa 29-54

CHAPTER IV.

General Characters of Cœlenterata—Classification—General Characters of Hydrozoa—Reproduction of Hydrozoa—Orders of

Hydrozoa—Hydridæ—Corynidæ—Sertularidæ—Calycophoridæ—Physophoridæ—Medusidæ—Lucernaridæ Pages 55-74

CHAPTER V.

Actinozoa—General Characters of Actinozoa—Classification—Zoantharia—Alcyonaria—Rugosa—Ctenophora—Tabular Classification of Cœlenterata 75-96

CHAPTER VI.

Echinozoa—General Characters of Echinozoa—Classification—Echinodermata—Echinoidea—Asteroidea—Crinoidea—Holothuroidea 97-116

CHAPTER VII.

Scolecida—General Characters—Classification of Scolecida—Platyelmia—Nematelmia—Rotifera—Tabular Classification of Echinozoa 117-132

CHAPTER VIII.

Annulosa—General Characters—Classification of Annulosa—Anarthropoda—Gephyrea—Annelida 133-145

CHAPTER IX.

Arthropoda—General Characters—Classification of Arthropoda—Myriapoda 146-149

CHAPTER X.

Insecta—General Characters—Metamorphosis of Insecta 150-166

CHAPTER XI.

Classification of Insecta—Ametabola—Anoplura—Mallophaga—Thysanura—Hemimetabola—Hemiptera—Orthoptera—Neuroptera — Holometabola — Aphaniptera — Diptera — Lepidoptera—Hymenoptera—Strepsiptera—Coleoptera Pages 167-181

CHAPTER XII.

Arachnida—General Characters—Classification of Arachnida—Trachearia—Pantopoda—Linguatulina—Tardigrada—Acarina—Pulmonaria—Arthrogastra—Araneina . 182-193

CHAPTER XIII.

Crustacea—General Characters—Classification of Crustacea—Cirripedia — Entomostraca — Branchiopoda — Pœcilopoda — Isopoda — Amphipoda — Stomapoda — Decapoda — Tabular Classification of Annulosa 194-215

CHAPTER XIV.

Mollusca—General Characters—Classification of Mollusca—Molluscoida—Polyzoa—Tunicata—Brachiopoda . . 216-240

CHAPTER XV.

Mollusca Proper—General Characters and Classification—Lamellibranchiata—Structure and Classification of Lamellibranchiata 241-253

CHAPTER XVI.

Gasteropoda—General Structure of Gasteropoda—Classification—Branchifera—Pulmonifera 254-267

CHAPTER XVII.

Pteropoda—General Characters and Structure of Pteropoda—Classification . . . . Pages 268-272

CHAPTER XVIII.

Cephalopoda—General Characters and Structure of Cephalopoda—Classification—Dibranchiata—Tetrabranchiata—Tabular Classification of Mollusca 273-299

PART III.—VERTEBRATE ANIMALS.

CHAPTER XIX.

Vertebrata—General Characters—Morphology and Physiology of Vertebrata—Skeleton—Digestive System—Hæmal System—Respiratory System—Nervous System—Reproduction—Classification of Vertebrata 300-328

CHAPTER XX.

Ichthyopsida—Pisces—General Characters and Structure of Pisces 329-348

CHAPTER XXI.

Classification of Pisces—Pharyngobranchii—Marsipobranchii—Elasmobranchii—Ganoidei—Teleostei—Dipnoi . 349-369

CHAPTER XXII.

Amphibia—General Characters and Metamorphosis of Amphibia—Classification—Ophiomorpha—Urodela—Anoura—Labyrinthodontia 370-388

CHAPTER XXIII.

Sauropsida—General Characters of Sauropsida—Reptilia—General Characters and Structure of Reptilia . Pages 389-396

CHAPTER XXIV.

Reptilia — Classification — Chelonia—Ophidia—Lacertilia—Crocodilia—Ichthyosauria—Plesiosauria — Dicynodontia—Ornithoscelida—Pterosauria 397-425

CHAPTER XXV.

Aves—General Characters and Structure of Aves—Habits of Birds 426-450

CHAPTER XXVI.

Classification of Aves—Natatores—Grallatores—Cursores—Rasores—Scansores—Insessores—Raptores—Saururæ 451-467

CHAPTER XXVII.

Mammalia—General Characters—Classification of Mammalia 468-482

CHAPTER XXVIII.

Classification of Mammalia — Implacentalia — Monotremata — Marsupialia 483-493

CHAPTER XXIX.

Placentalia—Edentata—Sirenia—Cetacea 494-509

CHAPTER XXX.

Ungulata—Artiodactyla—Omnivora—Ruminantia—Perissodactyla—Multungula—Solidungula—Proboscidea Pages 510-531

CHAPTER XXXI.

Carnivora—Pinnigrada—Plantigrada—Digitigrada—Rodentia 532-550

CHAPTER XXXII.

Insectivora—Cheiroptera 551-559

CHAPTER XXXIII.

Quadrumana—Bimana—Tabular Classification of Vertebrata 560-572

GLOSSARY 573-609

INDEX 611-634

LIST OF ILLUSTRATIONS.

Vignette—Head of African Lion (*Leo Africanus*).

Fig. Page
1. Morphology and Development of *Gregarinida* . 34
2. *Rhizopoda* 35
3. *Rhizopoda* 37
4. *Foraminifera* and *Radiolaria* . . . 39
5. Spicula of *Spongida* 42
6. Diagrammatic Section of Fresh-Water Sponge . 43
7. Morphology of *Infusoria* 48
8. *Infusoria* 52
9. *Noctiluca miliaris* 53
10. Morphology of *Cœlenterata* 56
11. *Hydridæ* 58
12. Cnidæ 59
13. Development of *Corynidæ* 63
14. Morphology of *Hydrozoa* 67
15. Morphology of *Corynidæ* and *Physophoridæ* . 68
16. Diagram of *Sertularid* 69
17. *Medusidæ* and *Lucernaridæ* . . . 70
18. Development of *Lucernaridæ* . . . 73
19. *Graptolidæ* 74
20. Vertical Section of *Actinia* 76
21. *Actinia mesembryanthemum* . . . 78
22. Morphology of *Sclerodermic* Corallite . . 80
23. Formation of Coral Reefs 85

Fig. Page

24. Morphology of *Alcyonaria* 88
25. *Pennatulidæ* 89
26. *Tubiporidæ* and *Gorgonidæ* 90
27. *Ctenophora* 92
28. Diagram of *Ctenophore* 93
29. Upper half of Shell of *Echinus esculentus* . . 100
30. Morphology of *Echinoidea* 101
31. Diagrammatic Section of *Echinus* . . . 103
32. Morphology of *Asteroidea* 109
33. *Asteroidea* 110
34. *Crinoidea* 112
35. *Crinoidea* 113
36. *Holothuroidea* 115
37. Morphology and Development of *Tæniada* . . 119
38. *Trematoda*, *Turbellaria*, and *Nematoda* . . 125
39. Morphology of *Rotifera* 129
40. Morphology of *Annulosa* 134
41. *Gephyrea* 136
42. *Hirudinea* 140
43. *Tubicola* 142
44. *Errantia* 144
45. *Myriapoda* 149
46. Morphology of an Insect 151
47. Mouths of *Insecta* 154
48. Digestive System of Beetle 159
49. Respiratory Apparatus of Insecta . . . 161
50. *Holometabolic* Metamorphosis of *Insecta* . . 163
51. *Hemimetabolic* Metamorphosis of *Insecta* . . 165
52. *Hemiptera* and *Orthoptera* 170
53. *Neuroptera*, *Aphaniptera*, and *Diptera* . . 172
54. *Lepidoptera* 175
55. *Hymenoptera* and *Coleoptera* . . . 178
56. Morphology of *Arachnida* 184
57. *Trachearia* 189
58. *Pulmonaria* 190
59. *Cirripedia* 196
60. *Entomostraca* and *Branchiopoda* . . . 199
61. *Trilobita* and *Eurypterida* 200

Fig.		Page
62.	*Pœcilopoda*	201
63.	*Isopoda* and *Amphipoda*	203
64.	Morphology of Lobster	206
65.	Diagram of Lobster	209
66.	Metamorphosis of Crab	212
67.	*Anomura*	213
68.	Morphology of *Polyzoa*	220
69.	Morphology of *Tunicata*	225
70.	*Tunicata*	231
71.	Morphology of *Brachiopoda*	234
72.	*Brachiopoda*	239
73.	Morphology of *Lamellibranchiate* Shells	243
74.	Diagram of *Lamellibranchiate*	250
75.	*Lamellibranchiata*	252
76.	Morphology of *Gasteropodous* Shells	257
77.	Teeth and Masticatory Apparatus of *Gasteropoda*	258
78.	Diagram of *Gasteropod*	260
79.	*Gasteropoda*	265
80.	*Heteropoda*	266
81.	*Pteropoda*	268
82.	*Dibranchiate Cephalopoda*	274
83.	Internal Shells of *Cephalopoda*	280
84.	Diagram of *Cephalopod*	283
85.	*Diabranchiate Cephalopoda*	291
86.	*Tetrabranchiata*	294
87.	Palæontology of *Cephalopoda*	296
88.	Comparative Morphology of *Invertebrata* and *Vertebrata*	301
89.	Homology of Vertebral Column	308
90.	Homology of Vertebral Column	310
91.	Osteology of *Mammalia* (Skeleton of Tiger)	313
92.	Ideal Section of *Mammal*	316
93.	Absorptive System of *Mammal*	317
94.	Blood-Corpuscles of *Vertebrata*	319
95.	Theory of Circulation in *Mammalia*	321
96.	Scales of Fishes	331
97.	Osteology of Fishes	334
98.	Morphology of Fins of Fishes	338
99.	Anatomy of Fish	341

Fig. Page
100. Theory of Circulation in Fishes . . . 343
101. *Pharyngobranchii* and *Marsipobranchii* . . 350
102. *Elasmobranchii* 357
103. *Ganoidei* 362
104. *Ganoidei* 365
105. *Dipnoi* 368
106. Osteology of *Amphibia* 374
107. Theory of Circulation in *Amphibia* and *Reptilia* . 376
108. Metamorphosis of *Amphibia* . . . 380
109. *Perennibranchiata* 383
110. *Caducibranchiata* 384
111. Osteology of *Chelonia* 398
112. Morphology of *Chelonian* carapace . . . 399
113. *Ophidia* 406
114. *Draco Volans* 414
115. Head and Tongue of *Chameleon* . . . 415
116. Diagram of Vertebral Articulations . . 417
117. *Crocodilia* : Teeth of *Gavial* . . . 418
118. *Pterosauria* (*Pterodactylus crassirostris*) . . 424
119. Osteology of *Aves* (Sternum) . . . 435
120. Osteology of *Aves* (Pectoral limb) . . . 436
121. Osteology of *Aves* (Pelvic limb) . . . 438
122. Digestive System of *Aves* 441
123. Respiratory System of *Aves* . . . 447
124. *Natatores* and *Grallatores* 454
125. *Cursores* and *Rasores* 459
126. *Scansores* and *Raptores* 462
127. *Insessores* 463
128. *Saururæ (Archæopteryx)* 467
129. Teeth of *Mammalia* 475
130. *Ornithorhynchus paradoxus* . . . 485
131. Pelvis of Kangaroo 488
132. *Marsupialia* (Kangaroo and Opossum) . . 491
133. *Edentata* (Armadillo) 495
134. *Sirenia* (Manatee) 500
135. Skull of Whalebone Whale and Baleen . . 502
136. *Cetacea* (*Balæna* and *Physeter*) . . . 506
137. *Ruminantia* (Stomach of Sheep) . . . 515

Fig. Page
138. Dentition of *Hyrax* 524
139. Dentition of Horse 525
140. Molar Tooth of African Elephant . . . 527
141. Molar Tooth of Indian Elephant . . . 528
142. Molar Tooth of Mammoth . . . 530
143. Feet of *Carnivora* 534
144. Walrus (*Trichecus rosmarus*) . . . 537
145. Skull of Bear (*Ursus*) 539
146. Skull of Porcupine (*Hystrix*) . . . 545
147. *Cheiroptera* (Skeleton of Bat) . . . 554
148. *Cheiroptera* (Heads of Bats) . . . 557
149. *Quadrumana* (Heads of Apes) . . . 562
150. *Quadrumana* and *Bimana* . . . 569

CHAPTER I.

INTRODUCTORY MATTER.

Divisions of Natural Science—Differences between Organic and Inorganic Bodies—Life and Organisation—Differences between Animals and Plants.

Before entering upon the details of any science, in however elementary a manner we may purpose to treat it, great advantage is to be derived from the consideration of certain preliminary and introductory matter. And this holds especially true of natural science, the many divisions of which are so intimately connected with each other, that it is necessary, for the sake of clearness and convenience, to map out and define the particular branch which it is our intention to study.

1. Turning our eyes abroad, and viewing the many objects by which we are surrounded, we naturally divide them into three great groups, known respectively as the Animal, the Vegetable, and the Mineral kingdoms. Thus, for all commonplace purposes, we know that a horse, a snail, and a worm, belong to the animal creation; that trees, shrubs, and flowers, are included in the plant world; whilst stones, rocks, and objects devoid of life, find a place in the mineral kingdom. We have thus, with little or no scientific know-

ledge, drawn a most important distinction between natural objects. We have separated those possessing *life* from those which are *lifeless;* in other words, we have constituted an *organic* and an *inorganic* series. With the first of these latter divisions the biologist has to do. The latter lies within the province of the geologist and mineralogist. The science of biology, therefore, includes the two subdivisions of botany and zoology: the former relating to the study of plants; the latter to that of the animal kingdom.

2. The characteristics by which inorganic objects are distinguished from organic objects, or those possessing life, may be summed up under five heads:—(*a*) *General Configuration;* inorganic bodies are bounded by straight lines and plane surfaces; organic bodies, on the other hand, are bounded by curved lines and by concave or convex surfaces. (*b*) *Chemical Composition;* inorganic bodies are composed of many elements, the compounds formed by these elements being simple and easily determinable; organic bodies are composed of but few chemical elements, but the combinations into which these may enter are exceedingly complex. (*c*) *Intimate Structure;* inorganised bodies are composed of similar particles—they present a homogeneous structure: organised bodies, on the contrary, are composed of heterogeneous or diverse parts. (*d*) *Mode of Increase;* inorganic bodies increase in size by a process of "accretion," that is, by the deposition of particles on their outside or external surfaces: organic bodies increase by the absorption and assimilation in their interior of

matter from the external world, and so exhibit the phenomena included under the term "growth," which is thus characteristic of living things. (*e*) *Cyclical or Periodic Change;* inorganised bodies present no defined order of phenomena which cannot be referred to chemical or physical action; organised bodies present a defined series of actions and changes, dependent on vital forces, and which, taken collectively, constitute the phenomena of *life*.

3. At the outset of our biological studies, we are naturally led to consider the question of life, and its nature. And it may be well at once to state, that no strict or satisfactory definition of life can be given. Speculations regarding its origin and nature have been indulged in from the earliest times, and even in the present day theory succeeds theory in rapid succession. Of late, a marked tendency has arisen to regard life and vital action as a mere force, analogous to the physical forces or natural actions which are everywhere and daily seen in operation around us. And, in accordance with this tendency, the essential point of the most recent life-theories is the investing of a common matter or "*basis*" of life, termed "*sarcode*," or "*protoplasm*," —which substance is found to enter universally into the composition of organic bodies—with inherent vital properties, and thus seeking to disconnect vital action from any except mere physical forces and laws. With hypothetical questions it is impossible safely or satisfactorily to deal; and in the present instance it may suffice merely to indicate the most universally accepted

notions of the nature of vital action. Generally speaking, vital actions, or those performed by living beings, seem to act antagonistically to many natural laws and forces. Life thus enables living bodies to resist actions which would otherwise tend to disintegrate and destroy them. The dead or lifeless body goes rapidly to decay, being acted upon by the chemical influences of the atmosphere. Pressure and friction, powerful agents in wearing and disintegrating dead or inert matter, harden and thicken the living body. Thus, the skin is thickened by constant pressure or friction. But in leaving these abstract results, and approaching the question of the origin or cause of vital action, great and almost insurmountable difficulties arise and impede our progress. Life has always been more or less associated, in the minds of those who have attempted to define it, with *organisation*, or the possession of organs and structures. So firm a hold had this idea obtained, that most of the definitions of life regard organisation as its *cause*. Thus, we find life defined by various writers as "the special activity of organised bodies" (Duges); and as "organisation in action" (Beclard). That this is an error is at once apparent, when we consider that we observe many bodies undoubtedly possessing life—examples of which are found among the *Protozoa*, or lowest animals, and the *Protophyta*, or most lowly-organised plants—but which do not exhibit the faintest traces of organised structures. On the contrary, we are forced by every consideration to believe that organisation is the *result* and not the *cause* of vital action, which may be considered as consisting of a series of phenomena, or established order of actions, differing in its various phases, not in kind, but only in degree. Thus, the life of the animal and the life of the plant are the same. The phenomena exhibited by the former differ from those of the latter only in intensity or direction.

4. Seeing, then, that both animals and plants are endowed with a common life, our next step must be to inquire into the differences, if there be any, between the two great sections of living things. To the unscientific observer this task may appear useless and futile. For the differences between the higher plants and higher animals are so obvious and ascertained, that there can be no hesitation in affirming the nature of one or other. But when we depart from those higher forms and descend to the lower sections of the organic series, when we compare the *Protozoa* with the *Protophyta*, the difficulty of drawing any definite line of demarcation between the animal and vegetable kingdoms is at once visible and apparent. If we say that (*a*) ***motion*** is characteristic of animal life, we are instantly refuted by the consideration that whilst the spores or germs of many true plants, such as the *Algæ*, or seaweeds, are endowed with considerable locomotive power, swimming about by means of the vibratile "cilia," or "eyelash-like" filaments, with which they are furnished; so, on the other hand, many true animals, among which the sponges, corals, etc., may be mentioned, are permanently rooted and fixed. The power of locomotion cannot therefore be taken as a

criterion of the nature of the organism. Nor can (*b*) *form* be considered as affording grounds for distinction and separation. Many polypes closely resemble plants, not merely in form, but also in their mode of propagation by "gemmation," or budding; and even high in the scale we find the "*Flustra*," or sea-mat—classed in the sub-kingdom *Mollusca* with our ordinary shell-fish—bearing such a decided resemblance to pale-brown seaweed, that it is almost invariably collected and preserved as such by visitors to the seaside, ignorant of its animal nature. On closer examination of the Flustra by aid of a magnifying glass, we are enabled to distinguish the little cells, in each of which a polype was contained. And conversely, many of the lower plants, both in their embryonic and mature states, resemble certain Protozoic forms. (*c*) *Chemical Science* also fails to assist us in drawing our line of separation. In the animal are found essentially the same elements which build up the vegetable organism. Indeed, the chemical investigation of certain forms has but rendered our task the more hopeless and confusing; for certain substances, long thought to belong exclusively to the vegetable economy, have been found entering intimately into the composition of animal structures. Thus *cellulose*, a substance nearly identical with starch, and until of late years considered to be an exclusive vegetable product, has been found in large proportion in the "*tunics*," or outer coverings of Ascidian Molluscs, or "sea-squirts," as they are popularly called; and the *chlorophyll*, or green colouring matter of plants, occurs in many microscopic animalculæ, —such as *Stentor* among the *Infusoria*,—the animal nature of which is indisputable. Microscopic investigation cannot determine any difference or distinction, showing, as it does, that the (*d*) *internal structure and ultimate tissues* of animal and plant are identical —these consisting in either case of molecular, granular, cellular, or fibrous structures. So unsatisfactory, then, in a general way, are the results which even careful modes of investigation yield, when applied to the specific distinction of the lower forms of life, that some authorities have proposed the construction of an intermediate kingdom, as a means of solving the difficulty, or rather of rendering their labours the less confusing. To this third or intermediate division the term "*Regnum Protisticum*" has been applied; and to this kingdom, those forms, concerning the nature of which difference of opinion exists, are by some naturalists allocated. It may only further be mentioned, in noticing this subject, that this plan does not meet with very general acceptation, the adoption of the system tending only to render the labour of distinction more confusing in its details.

In the (*e*) *nature and mode of assimilation of the food*, and the results of its conversion *within the organism into nutritive material*, are found the most reliable points on which we may found grounds of distinction between the nature of the animal and that of the plant. The *nature* of the food differs in many and important ways. Plants, as a rule, subsist upon dead or inorganic matter—such as water, gases, and mineral matter; and from these substances they elaborate organised materials, among which the vegetable products starch and sugar stand most conspicuous. Animals, on the contrary, require for subsistence living matter, or matter already organised, which they convert into dead or inorganic matter. This organic matter is principally derived from the plant world; and hence in this, as in the other points to be noted, plants act conversely to animals—the former being the great producers in nature, whilst the latter are the consumers. The interchange of gases between the two kingdoms forms a second point in the distinction. Animals excrete or give out, with heat and water, as the result of their tissue-waste, a large proportion of a gas named *carbonic acid,* whilst they absorb another gas called *oxygen,* which forms part of the atmosphere, and which is appropriately termed "the great supporter of animal life." The maxim that there is no waste in natural operations finds in this a fitting illustration, since plants greedily absorb the carbonic acid given off by animals. They further decompose the carbonic acid into the carbon and oxygen of which it is composed, retain the carbon for the uses of their economy, and set free or liberate the oxygen, which is thus rendered fit for re-absorption by animals. In short, what the animal excretes (carbonic acid), the plant absorbs; and what the plant excretes (oxygen), the animal absorbs. In other words, the reaction upon the atmosphere of the animal is the reverse of that of the plant. The nature of the food being thus different, we are prepared to find that the apparatus for its assimilation and conversion into nutritive matter will differ in like manner. The nutritive organs of the plant are *external*, and consist of the root, stem, and leaves, together with the intercellular canals and spaces existing in the tissues of the organism; and by these various parts and organs the substances necessary for the maintenance of life are absorbed and diffused throughout the system. The characteristic form of nutritive apparatus in the animal, on the contrary, is that of an *internal* cavity, digestive sac or stomach, into which nutritive material is received, and in which it is digested, assimilated, and otherwise prepared for the uses of the economy; and to this simple typical structure there is added, in the case of the higher animals, the complicated series of organs constituting the digestive system.

Lastly, the possession of a nervous system by the typical animal forms, and the absence of such a system in plants, has also been included by some observers in the distinctive points between the animal and vegetable series.

CHAPTER II.

DIVISIONS OF BIOLOGICAL SCIENCE.

Morphology, Physiology, and Distribution — Specialisation of Function—Morphological Types—Homology and Analogy —Symmetry of Animal Forms—Classification.

1. HAVING defined our science, and also examined the nature of life and organisation, we must next point out the mode of examination of living forms, or of biological research. Every living being admits of being studied under three aspects. To know it thoroughly, we must observe it from three different yet connected points of view. The following table will illustrate the divisions of biological science :—

BIOLOGY—Science of Life.

I. *Morphology.* (Science of Form).	(a) Anatomy.
	(b) Development.
	(c) Taxonomy.
II. *Physiology.* (Science of Function.)	(a) Function of Nutrition.
	(b) Function of Reproduction.
	(c) Function of Correlation, or Irritability.
III. *Distribution.*	(a) In Space (Geographical).
	(b) In Time (Geological).

We have, firstly, a science which deals with the form and structure of the organism, and this we term Morphology. Secondly, we have the science of function—Physiology. And, lastly, we have the Distributional aspect of our science, by which we ascertain the habitat of an animal, or the conditions in which it exists with regard to the external world. It will be further observed, that each of these primary sections is divided into subsidiary branches. Thus, under the head of Morphology, we have *Anatomy*, *Development*, and *Taxonomy*, each subdivision dealing with a separate aspect of the main science; and we shall now endeavour to explain the object of each section.

We may, firstly, study an animal Morphologically—that is, consider its form and structure. Under this head we observe its various structural features. By *Anatomy* we investigate its external and internal appearances, the position and relations of organs and parts. We thus obtain a knowledge of its structure as a fully-formed being. But if we wish to study it through the various stages leading from the embryonic to the mature and adult state, we must call to aid the second department of morphological science, and consider the subject of *Development*. From these, we pass by an easy transition to the consideration of its place in the scale of life, and for which task our knowledge of its structure has fully prepared us. We thus include the third division—that of *Taxonomy* or *Classification*. Having investigated the Structural relations of the animal, we next proceed to inquire into the *Functions* which, as a living being, we expect it to perform. This leads to the consideration of the science of Physiology, which may accordingly be termed the Science of Function. Let us suppose, by way of illustration, that we have examined a fish morphologically. From our knowledge of its anatomical structure, we have ascertained the structure of its body. We can indicate the situations of its various organs—stomach, liver, intestines, etc. ; can describe its circulatory and respiratory apparatus ; and have determined the relations of its nervous system. But if we wish to know *how* the food is digested, how the products of digestion are absorbed, how the heart beats, and what it drives through the vessels ; how the blood is purified, and how the nervous system controls and directs the powers of the organism—we must turn to Physiology, which explains the *duties* or *functions* the various organs perform, just as morphology taught us their form and structure. Under this head we have also three subdivisions, representing the great functions performed by every living being. First in order comes the function of *Nutrition*, by which the organism provides for its support and nourishment ; and, under this department, we investigate the digestive, absorptive, circulatory, and respiratory processes—how nutrient matter is prepared and applied to the uses of the economy. Secondly, the function of *Reproduction*, by which the animal or plant reproduces its species and perpetuates its race. And, lastly, we have the function of *Correlation*, *Innervation*, or *Irritability*—under which head we examine the nervous system, or means whereby the organism maintains relations with its fellows and with the external world. The third and last division of biology is that of Distribution. By this branch we determine the place an animal occupies in the globe at the present time, or the conditions under which it existed in time past. The former aspect deals with the *Geographical* distribution of the organism; the latter investigates its *Geological* relations. Thus the Marsupial, or Pouched Mammals, represented by the kangaroos and their allies, occupy a very limited geographical area, being almost entirely confined to Australia; whilst their geological relations present many features of similar import and interest.

2. Animals, it will thus be seen, may differ from each other, either as to structure (morphologically), or as to the degree of perfection and manner in which the functions of the body are carried on (physiologically). These differences form the basis of our system of classification, since they determine for us whether an animal be of high or of low organisation. According to the relations expressed by the facts elicited by its study from these two chief aspects, the place and rank of a living being in the great series is determined. The physiological difference relates to function, and to this first point the term "Specialisation of function," has been applied. The second and morphological distinction expresses the application to taxonomical science of the facts brought out by the investigation of forms and structures. These facts are exemplified by the

construction of six great plans of animal structure, termed "morphological types." Each of these two points demands some explanation, and we shall begin with the physiological difference, since it serves in a manner to explain the other.

3. "SPECIALISATION OF FUNCTION" may be best understood by giving a few examples of its application. Every animal performs the three great functions already mentioned: it nourishes itself, reproduces its species, and has certain relations with the surrounding media. It is obvious that the animal of low organisation, the functions of whose body are neither complex nor intricate, will be furnished with organs of correspondingly simple structure. Thus the Amœba or Proteus-Animalcule (Fig. 2), familiar to every microscopist, and which consists of a simple structureless mass of whitish jelly-like substance, termed "sarcode" or "protoplasm," is unprovided with any digestive system; no trace of an internal cavity, or of the most rudimentary stomach-sac, is seen. When it wishes to eat, it sends out prolongations of its soft body, grasps the particle of nutrient matter, which is then drawn within the body of the creature, and engulfed in the soft gelatinous texture of its body. The particle of nutriment is now subjected to the digestive action, such as it is, and the indigestible part of the food is cast out at the portion of the body nearest to the external medium in which it lives. The function of nutrition, in this case, cannot be said to be specialised or differentiated at all, since any part of the animal's body subserves the digestive or nutritive function. In the

Hydra (Fig. 11) we find a creature of better defined form and habits. The nutritive function has become specialised, although to no great extent. It has, however, advanced in a marked degree, and we have in the *Hydra* not only a well-defined body-cavity, answering the purpose of a digestive sac, but also a mouth and tentacles, or organs for the prehension of nutriment, and for its conveyance to the oral aperture. The effete portion of the food is cast out by the mouth. Passing upwards, we find the *Flustra* (Fig. 68), or sea-mat, illustrating the further specialisation of the nutritive apparatus. We find in the *Flustra* not only a mouth and tentacles, but a true stomach, specialised or separated from the cavity of the body, and thus differing materially from the *Hydra*, in which the cavity of the body served for a stomach-sac. An intestine is now given off from the stomach-sac; and this, whilst serving to extend and increase the digestive area, also carries off the effete products of digestion, which are thus expelled by a distinct anal aperture. The *Snail* or *Whelk* presents us with a condition of functions and organs still more advanced. Each part of the digestive function in this latter case has become more specialised, and with the complexity of the function fresh organs are added, each devoted to a separate portion of the work. The office, in short, which was performed by the simple body-cavity of the *Hydra*, or the still more simple body of the *Amœba*, is now broken up into many separate divisions, each division having an organ, or series of organs, allotted to its performance. In the Snail or Whelk we have a mouth, furnished with salivary glands, preparing the food for digestion in the stomach. The stomach and intestines are now larger and better defined, whilst a capacious liver, furnishing bile, for the more perfect assimilation and separation of the digestible part of the food, envelops the other viscera in its voluminous folds. Further, we have now a distinct heart and vessels for the due circulation of the blood or nutrient fluid, and the presence of these latter organs indicates a further differentiation of the nutritive function, the duty performed by the heart and vessels being carried on in the lower forms by the tissues generally of the body. We need scarcely trace further the progress of the differentiation, save remark, that in the highest forms of all the process becomes more and more intricate, organs being superadded to the former ones, as the duties of these latter become more complex. Specialisation of function is thus seen to be intimately associated with specialisation of organs. Indeed, it is impossible to think of the former without, of necessity, including the latter in the thought; or, to use the words of Professor Allman, "Specialisation of organs and specialisation of function go hand in hand." Milne Edwards has not inaptly applied to this distinction the term "physiological division of labour," thereby implying that in the lower animal the function is subserved by few organs and tissues, and that in the higher organism, the process, being more complex, requires additional organs of finer construction to carry on the work. Or, to use the succinct words of Professor Huxley, "the difference between the powers of the lowest plant or animal, and those of the highest, is one of degree, not of kind, and depends, as Milne Edwards long ago so well pointed out, upon the extent to which the principle of the division of labour is carried out in the living economy. In the lowest organism all parts are competent to perform all functions, and one and the same portion of protoplasm (as in Amœba) may successively take on the function of feeding, moving, or reproducing apparatus. In the highest, on the contrary, a great number of parts combine to perform each function, each part doing its allotted share of the work with great accuracy and efficiency, but being useless for any other purpose."

4. The *Morphological* difference consists in the distinctions between the types or plans upon which animal forms are constructed. Every animal can be referred to one or other of six great groups termed "MORPHOLOGICAL TYPES." These "types," or plans of structure, also represent six great primary divisions of the animal kingdom, and thus constitute the groundwork or basis of the present system of classification. They are respectively named :—

I. PROTOZOA.
II. CŒLENTERATA
III. ECHINOZOA.
IV. ANNULOSA.
V. MOLLUSCA.
VI. VERTEBRATA.

A short description of each of these groups will tend to the better understanding of the generalisation of the subject.

I. PROTOZOA.—The *Protozoa*, as the name implies, form the lowest division of the series. The animals comprising this division are, for the most part, of microscopic size. They exhibit no "symmetry," or definite arrangement of parts. Indeed, their characteristics are principally negative; they are distinguished rather by their want of organs and defined tissues, than by the possession of these structural elements. In this sub-kingdom, as might be supposed, "specialisation of function," together with the "morphological type," is of the lowest grade. Examples of this sub-kingdom are found in the Amœba, Sponges, and many microscopic animalculæ.

II. CŒLENTERATA.—The *Cœlenterata* possess a distinct form; the symmetry is of the radial description, united with bilateralism; in other words, the *merosomes*, or elements of form, are said to be "disposed in a radial manner round a longitudinal axis," whilst at the same time the body can in many instances be divided into two equal halves (*Bilateralism*). A stomach-sac, or digestive organ, exists in the higher forms, but this sac is imperfect in structure, as it opens freely into the general cavity of the body. A nervous system, if present, is but feebly differentiated. The *Cœlenterata* are represented by such forms as the Hydra, Sea-anemone, Corals, etc.

III. ECHINOZOA.—In this sub-kingdom or type, the symmetry is typically radial and bilateral, as in the preceding group. A digestive system, completely specialised and shut off from the general cavity of the body, exists, whilst a distinct vascular or circulatory apparatus, together with a true nervous system, is present in the higher forms. Star-fishes, Sea-urchins or *Echini*, and certain worms, represent this type, which, from certain affinities with the next and higher group, is sometimes termed the *Annuloida*.

IV. ANNULOSA.—The consideration of the Annulosa introduces us to a very characteristic type of animal structure. The animals comprised within the limits of this group are composed of numerous definite joints, segments, or "somites," arranged along a longitudinal axis. The symmetry is of the bilateral description. The jointed or segmented structure of the Annulosa is in most cases exceedingly distinct. The digestive system is now further specialised, the nervous system consisting of a chain of nervous cords situated ventrally, or on the floor or inferior aspect of the body. The respiratory, and blood-vascular or circulatory systems, are highly differentiated; the heart, representing the latter system, being in the Annulosa situated dorsally, or in the region of the body opposite to that in which the nervous system is placed. This type is represented by worms, crabs, and insects. Cuvier gave to his group, embracing these forms and their allies, the name *Articulata*, or "jointed" animals, from the segmented nature of their bodies.

V. MOLLUSCA.—The *Mollusca*, represented by all our ordinary shellfish—such as Oysters, Limpets, etc. —by Cuttle-fishes, and by several other typical but less familiar forms, possess bilateral symmetry, and definite arrangement of organs and parts. They possess the power of secreting a hard exo-skeleton, to which the term "shell," is commonly applied, and which serves to protect the otherwise "soft" bodies of these creatures. The chief characteristic of this type is in the differentiation of the nervous system, which presents a very definite arrangement, consisting, in the typical forms, of three pairs of nerve-masses, disposed in a certain manner through the body.

VI. VERTEBRATA.—This last and highest group, to which Fishes, Reptiles, Birds, and Mammals belong, is distinguished by the possession of an internal skeleton, having for its basis the vertebral column, spine, or backbone. The symmetry is bilateral, combined with a zonal arrangement of parts, similar to that seen in the Annulose type. The chief characteristic by which the Vertebrata are to be distinguished, is the very high differentiation of the nervous centres, which are now shut off from the other viscera and regions, an arrangement contrasting forcibly with that observed in the lower groups. The ventral, inferior, or lower arches of the vertebral column (ribs), form cavities for the reception and protection of the digestive, respiratory, and circulatory organs.

Animals, seemingly, and at first sight, constructed after widely divergent plans or types, may be found, on closer examination, and on careful comparison with neighbouring forms, to belong to one and the same primary group. Thus the worm, insect, and crab, are, by reason of agreement in their fundamental structure, classified together in the Annulosa; and the fish, serpent, and bird, presenting no external features in common, are found to correspond in original and primary structure. It follows from the previous considerations, that an animal whose functions are not specialised to any great extent must exhibit a corresponding lowness of organisation; and these types or plans of structure may be considered as the expression, in a convenient form, of the degree of differentiation or perfection to which the organs and functions of the included forms have attained.

5. HOMOLOGY AND ANALOGY are farther aids in the classification and assorting of animal forms. Homology means identity in *structure;* Analogy means identity in *function.* Thus the former may be termed a morphological, whilst the latter may be considered a physiological distinction. As familiar examples of these terms, we may select the arm of man and the wing of the bird, which, being formed on the same fundamental plan, are said to be *homologous.* The wing of the bird and that of the butterfly are *analogous,* both being used for the purpose of flight. The wing of the bird and that of the bat are both *homologous* and *analogous;* both are constructed on the same type, and both are used for locomotion in the aërial medium. A repetition of similar parts in the same animal, or of parts homologically constructed, constitutes "*serial homology.*" An example of this latter variety may be found in the

variously altered and modified segments of the lobster's body, which, notwithstanding their apparent dissimilarity, are referable to one and the same plan.

6. SYMMETRY OF ANIMAL FORMS.—By the symmetry of an animal form is meant the disposition or arrangement of the primary elements into which the form is capable of being resolved. And a careful examination of the great types, or plans of structure, shows that the disposition of the elements of form takes place after one or more defined modes in each of the types. For convenience sake the naturalist invents an ideal element of form, to which Professor Allman has applied the term "*merosome;*" "the result of the regular repetition of the same element of form" being the particular kind or kinds of symmetry characteristic of any given type. Three kinds of symmetry are recognisable in the animal series, these varieties being respectively known as "*Bilateral,*" "*Radial,*" and "*Zonal*" symmetry. A "Bilateral" symmetry is that in which the form can be equally divided in the mesial plane, or, in other words, divided into two equal halves. In "radial" symmetry, the "merosomes" are disposed "radially" around a central axis; whilst in "zonal" symmetry the merosomes are arranged in zones, one after another, in a longitudinal axis.

Thus, in a worm, representing the annulose type of structure, the "merosomes" are represented by the segments or joints of the body, which are arranged zonally along a longitudinal axis. As we can also divide our worm bilaterally, or into two equal halves, the symmetry is said to be of the "zonal" type, combined with "bilateralism." The "radial" symmetry is seen in the Echinozoa, represented by the Echinus or Sea-urchin, in which the "merosomes" are arranged in a radial manner; and here, also, bilateralism may be said to exist. The fish, also, as representing the vertebrate type, presents the same symmetrical features as the worm, the zonal arrangement being witnessed in the arrangement of the segments of the vertebral column. These characteristic forms of symmetry thus afford additional grounds of distinction or relation between the various groups, into which, as we shall in the next place see, the animal series is divided.

7. CLASSIFICATION.—Our introductory matter has fitted us for the consideration of the system of *classification*, which may be defined as "a comprehensive expression of the facts and laws of morphology and physiology." To use the words of Huxley, "By the classification of any series of objects is meant the actual or ideal arrangement together of those which are like, and the separation of those which are unlike; the purpose of this arrangement being to facilitate the operations of the mind, in clearly conceiving and retaining in the memory the characters of the objects in question." The whole subject of classification, however, is one of much difficulty. This may be due partly to the various and different characteristics by which the several groups are subdivided, and also to the combinations of systems which have taken place at various stages in the history and progress of our science. Then, too, new systems,

or parts of systems, are continually springing up, as the older ones are found inadequate to meet the exigencies of increasing knowledge.

From the study of morphological science we have elucidated six great types or plans of animal structure; and in the present system of classification these are used under the term of "*sub-kingdoms*," as primary groups, readily susceptible of division into smaller groups.

The system of classification may be expressed thus:—

Kingdom.
  Sub-Kingdom.
    Class.
      Order.
        Family.
          Genus.
            Species.

Or we may simply affirm that the whole animal kingdom is divided into sub-kingdoms, each of these latter being further divided into classes; the classes into orders; the orders into families; the families into genera; and the genera into species. In ascending the scale, however, and explaining the meaning and application of these terms, our difficulties arise. *Species*, which we may regard as the unit of classification, is a term, regarding the nature of which much discussion has existed from all time past, and which, for some time to come, appears as likely to be continued. To define the limits of species is, in the present state of our knowledge, absolutely impossible, the inability arising not so much, perhaps, from lack of information, as from the very many considerations involved, in attempting to include within the limits of a mere definition the numberless facts and ideas included in the term. Nor are naturalists at all agreed as to the exact limits of the term, one party considering as a true species what another sect might hold to be a mere *variety* of the species. For a simple yet expressive enough definition, we may refer the reader to that of Professor Jones, which in plain language embodies what we believe to be the gist of the term. By Professor Jones species is defined as "a number of animals so closely resembling each other that they all might be supposed to be the offspring of the same parents, and in turn to give birth to progeny exactly resembling themselves." Thus, the common rabbit resembles its parents in most particulars, and its progeny will, in ordinary circumstances, bear the likeness of their parents. Food, climate, and other physical agencies may, however, operate on the species, producing changes which, whilst not altering to any great degree the appearance of the animal, may yet so change its habits and life, as to give rise to *varieties* of the species.

Genus (plural *genera*) embraces several species, which resemble each other in some important characters, thus sufficing for their more immediate distinction and separation from other animals. Thus, the hare bears so close a resemblance to the rabbit, that we include them both in one genus. As, however, they differ in certain minor particulars, we are warranted in referring them to different species. So also with the mouse and rat, and many other animals, which the mind will readily suggest to itself.

A *Family* is a minor group, including a number of genera, and inserted for the sake of convenience, and to avoid overcrowding the Orders, where the number of forms is very numerous.

An *Order* embraces *genera* allied to each other by some important general feature in their economy. Thus, the hare and rabbit are both furnished with sharp, chisel-shaped incisor, or front teeth. But in certain other animals, such as rats, mice, squirrels, beavers, porcupines, etc., this peculiar arrangement of the dental apparatus is also found; and this characteristic feature we account of sufficient value to unite these varied forms together in the Order *Rodentia*, or gnawing quadrupeds.

A *Class* includes many orders, united by some still broader feature or features. Thus, animals comprised in the order *Rodentia* suckle their young; but so also do whales, horses, dogs, sheep, elephants, seals, bears, etc. This grand characteristic is, therefore, sufficient to unite these various orders in a common *Class*, that of the *Mammalia*, or animals nourishing their young by the secretion of milk. The Mammalia, in common with fishes, reptiles, and birds, possess an internal skeleton and vertebral column; and hence the subkingdom *Vertebrata*, also a great morphological type, is constituted. Such is a familiar description of the principles of the present system of classification. Much that may at first appear difficult and incomprehensible will be rendered facile and plain as the student advances in the study, and familiarises himself with examples of the various terms and their application. Practice and association will soon accomplish what the most lucid description may fail to impart or render plain.

In scientifically naming animals, and plants also, we use the *binomial* system, by which, as the term implies, we give to every organism two names. The first of these is the "*generic*" term, whilst the latter indicates the "*species.*" Thus, the rabbit is named *Lepus cuniculus,* and the hare *Lepus timidus;* the domestic mouse *Mus decumanus;* the harvest mouse *Mus messorius;* and the rat, *Mus rattus.* The following examples will serve to show the classification, and render the process of differentiation plainer:—

SUB-KINGDOM.	CLASS.	ORDER.	FAMILY.	GENUS.	SPECIES.	COMMON NAME.
Vertebrata.	Mammalia.	Ruminantia.	Ovidæ.	Ovis.	Aries.	Sheep.
Mollusca.	Cephalopoda.	Tetrabranchiata.	Nautilidæ.	Nautilus.	Pompilius.	Pearly Nautilus.
Annulosa.	Annelida.	Oligochœta.	Lumbricidæ.	Lumbricus.	Terrestris.	Earthworm.

CHAPTER III.

PROTOZOA.

General Characters—Classification—Gregarinida—Rhizopoda—Spongida—Infusoria.

THE Protozoa form the first and simplest of the sub-kingdoms. As the term implies, the forms comprised within the limits of the division are of the most lowly organisation, and exhibit a corresponding simplicity of structure. Many Protozoa have been—and several forms by some observers still are—regarded as finding a more appropriate place among the Protophyta, or lower plants; and it is in the consideration of the forms and relations of these simple organisms, that the futility of attempting strictly to confine the boundaries of either the animal or the plant series is most clearly visible. In defining the sub-kingdom, we may, firstly, notice that the Protozoa are for the most part of microscopic size. Their bodies are composed of a soft flesh-like substance, to which the name of "sarcode," or "protoplasm," has been applied; and no definite symmetry of body, or differentiation of organs and tissues, can, on the whole, be said to exist. The Protozoa, in fine, appear to be characterised rather by negative than by positive characteristics; rather by the non-possession, than by the possession, of defined organs, tissues, or structures. And, lastly, when we add that they are generally aquatic in their habits—inhabiting both fresh and salt water—we shall have completed the elements of a general definition of the sub-kingdom.

The "sarcode," or "protoplasm," of which the bodies of the Protozoa are composed, has been defined as a "nearly structureless albuminous substance," yet apparently possessing so many of the qualities necessary for vitality, and for carrying on the operations exhibited by, and consequent on, the possession of life, that Professor Huxley has applied to sarcode the title of "physical basis of life." Thus, familiarly in the case of the *Amœba*, or Proteus-Animalcule (Fig. 2), and notably in many other instances, the sarcode of which the animalcule's body is composed subserves in itself the functions of a digestive organ, of a circulatory medium, and of a reproductive apparatus; and it can also produce other structures, such as shells of intricate construction; in short, vital phenomena, of the most complicated description, are witnessed to be produced by a seemingly structureless substance. And the generalisation of function thus perceived indicates that this sarcode matter partakes of and contains inherent vital properties; the result of investigations on this subject being the construction of the most recent theories of the nature of life and vital action, the tendency of which, as previously noticed, is to regard life as a condition peculiar to matter, and not as a separate and distinct principle.

Locomotion is effected in the Protozoa by a variety of means. As in the case of the Amœba, movements may be carried on by means of extensile and retractile prolongations of the sarcode—the term "pseudopodia," or "false feet," being applied to these organs. In the Infusoria, on the other hand, locomotion is effected by means of the characteristic vibratile "cilia," or filaments, with which the bodies of these animalcules are provided. The Sponges, representing another section of the Protozoa, remain, in their native state, rooted and fixed to the sea-bed.

Classification.—The Protozoa are divisible into four classes :—

Class I.—GREGARINIDA.
Class II.—RHIZOPODA.
Class III.—SPONGIDA.
Class IV.—INFUSORIA.

The term *Astomata* is sometimes applied collectively to the first three classes, no distinct mouth being present in these groups ; the Infusoria, in which a distinct oral aperture is found, being known as the *Stomatous* Protozoa

Class I. GREGARINIDA.—The *Gregarinida* form a group of limited extent, and of exceedingly simple structure. They are found, as parasites, inhabiting the bodies of insects, worms, and allied forms ; and this characteristic, together with the fact that they are incapable of emitting the "pseudopodia," so marked a feature in the succeeding group, is sufficient to constitute a definition of the class. The *Gregarina* of the earthworm (Fig. 1, *a*) may be taken as typically representing the group. It consists of a structureless, ill-defined, outer wall or envelope, enclosing semi-fluid and granular contents. At one portion of the body, a spherical mass, termed the "*nucleus*," is observable; and this, in turn, may contain one or more smaller particles, to which the name of "*nucleoli*" is applied. The office of the nucleus, or central body, as we shall presently see, is intimately connected with the reproductive process. The general structural features of this creature forcibly call to mind the constitution of the simple elementary body known as the *cell;* and, indeed, physiologically considered, the vital processes witnessed in the Gregarina are essentially those exhibited by the active and simple living cell.

The Gregarina subsists by simple imbibition and absorption of fluids through the simple walls of its body, no digestive apparatus of any kind being found. The reproductive process is extremely interesting, as affording a fitting illustration of Von Baër's great law that "development proceeds from the general to the special;" in other words, that up to a certain point in the process of development the changes observed in the ovum or egg are common to the entire sub-kingdom, or type of structure, to which the form belongs; but that at this point the development specialises itself, and, in accordance with the degree of specialisation observed, a higher or lower form is produced. This discovery completely revolutionised the older theories and ideas of development, by which it was supposed that in the development, say of any of the higher vertebrates, the stages in that process corresponded to the various lower types of structure into which the entire series is divided; or that, in the case of the vertebrate embryo, the stages of development represented the various and perfect types of structure known as the Protozoa, Cœlenterata, Echinozoa, Annulosa, and Mollusca. Von Baër's researches disproved this theory, and showed that a common point of divergence was reached in the developmental process, and that the characteristic features of the type of structure to which the ovum belonged were immediately thereafter exhibited—these features continuing to grow more and more specialised until the perfect form was finally evolved. In the reproductive process of Gregarina, the principal points in the development of the animal ovum may be conveniently studied. Two Gregarinæ come together and coalesce—or one individual may be observed in itself to exhibit the changes about to be described—the united Gregarinæ, or the single individual, as the case may be, next form a spherical or rounded mass, which soon developes around it a thickened structureless envelope or "cyst." The "nucleus" then disappears, and the contents of the cyst undergo division and segmentation, until the interior of the sphere is seen to be filled by a mass of curious spindle-shaped bodies, to which the term "pseudonavicellæ" is applied (Fig. 1, *b*, *c*). The next stage consists in the rupture of the cyst, the "pseudonavicellæ" (Fig. 1, *d*) escaping into the surrounding medium, and requiring but little further change to make them resemble the Gregarina or parent organism from which they sprang.

Class II. RHIZOPODA.—The Rhizopoda, or "root-footed" Protozoa, are defined as Protozoa "capable of emitting extensile and retractile prolongations of their body-substance" (Allman). Of this class the *Amœba* (Fig. 2, *a*, *b*) may be taken as a characteristic example. This animalcule is found amid the duckweed, which, during the summer months, fringes every stagnant pool. Its name is derived from the Greek *amoibe*, change, in allusion to a peculiar feature in its organisation, in virtue of which it constantly alters its shape (Fig. 2, *b*), the soft protoplasmic body being thrown into every conceivable form. The "pseudopodia," or "false feet," furnish a definite feature of the group. These consist of variously-shaped processes, formed by the extension

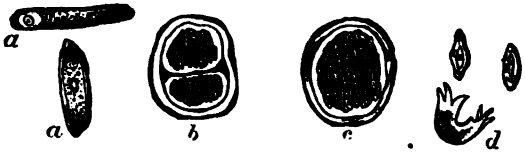


Fig. 1. MORPHOLOGY AND DEVELOPMENT OF GREGARINIDA.

a a, Adult *Gregarinæ*; *b*, encysted condition of *Gregarina*, showing pseudonavicellæ contained in the interior of the cyst; *c*, more advanced stage of *b*, the septum having disappeared; *d*, free pseudonavicellæ, the lower figure presenting an amœbiform appearance.

of the outer sarcode of the body. They appear to be produced spontaneously, and from any part of the body-margin; their evident function is to act as prehensile organs, for grasping particles of nutrient matter, but they, in many cases, constitute locomotive organs also.

The processes of life in Amœba are exceedingly simple, and may be well observed by feeding the animalcule on coloured substances, such as indigo or carmine, in a fine state of division,—a plan pursued by Ehrenberg in his researches on the Infusoria. A piece of this coloured "food" may be seen to approach the Amœba, when, at once, it extends towards the particle two of the "pseudopodia," with these it encloses the little mass of nutriment, the pseudopodia melt into one another at their extremities, and finally the morsel is seen to be deposited, or rather engulfed, within the body of the creature. The entire process of prehension and deglutition, if we may use the term, in the Amœba,

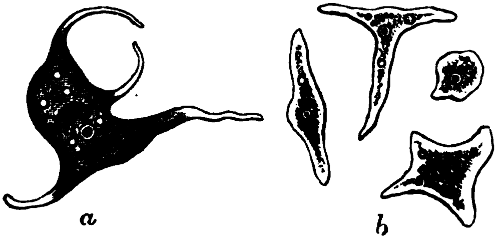


Fig. 2. RHIZOPODA.

a, *Amœba radiosa*, showing pseudopodia, nucleus, contractile vesicle, and food-vacuoles; b, *Amœba diffluens*, in various stages of contraction.

has been not inaptly compared to the thrusting of a solid substance, such as a stone, into the heart of a mass of soft matter, such as clay. Whilst retained within the body of the creature, the nutritive portion of the food will be extracted by some process analogous to digestion, and the effete, or indigestible portion, cast out, by a simple reversion of the process by which it was taken in.

Anatomically viewed, several structures of importance are to be noticed in the Amœba. A nucleus (Fig. 2, *a*), similar in all essential points to that observed in Gregarina, is firstly seen; and, with this primary centre, several other nuclei may be associated, the function of each being to subserve, in some degree at least, the reproductive process. A second structure is noticed in a clear spot or space, formed by a small cavity, the position of which in the body of the animalcule appears to be undefined. From the fact that this space is observed to expand and contract, with a regular and defined motion, it has received the name of "contractile vesicle" (Fig. 2, *a*). It has been generally regarded as a circulatory organ or heart, serving to distribute throughout the body the nutritive fluid derived from digestion, or, as has been supposed, simply fluid, derived from the surrounding water. Around the little food-particles, which, as we have seen, are variously deposited throughout the body, clear spaces, known as "vacuoles," are seen to form. The formation of these vacuoles is, in all probability, connected with the solution and digestion of the food. No nervous system, or analogous structures, have been observed in the Amœba, the low organisation of the creature precluding the idea of the existence of at least any defined organs pertaining to the function of relation. That the Amœba and its allies possess certain relations with the external world is indisputable, but these relations are to be regarded as connected rather with a general sensibility than with any defined or specialised sensations. Reproduction may be accomplished in various ways, among which the most familiar are those, firstly, by simple fusion or division of the body-substance, each part becoming a distinct and separate organism; and, secondly, by a process exhibiting all the stages, similar to those observed in the reproduction of Gregarina.

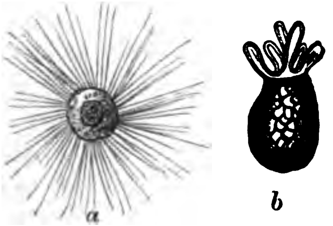


Fig. 3. Rhizopoda.

a, *Actinophrys Sol*, showing the pseudopodia; b, *Difflugia*, with anterior protruded pseudopodia.

The Rhizopoda are divided into three orders, the first of which, that of the (*a*) *Amœbea*, is represented by the Amœba (Fig. 2, *a*, *b*), and by *Difflugia* (Fig. 3, *b*), the body in this latter form being contained within a stiffened case or membrane, formed by the deposition in the sarcode of particles of sand and other material. From the single aperture, situated at what may be regarded as the anterior extremity of the creature, the pseudopodia are protruded, as depicted in the accompanying figure. The *Actinophrys Sol*, or "sun-animalcule" (Fig. 3, *a*), also exemplifies this order.

(*b*) Order *Foraminifera*.—If we suppose an Amœba to be endowed with the power of secreting an external shell composed of carbonate of lime, and that through holes (*Foramina*) in the shell the "pseudopodia" could be protruded, we will acquire a sufficiently clear idea of the morphology and relations of the present group. The sarcode of which the bodies of the Foraminifera are composed, differs in certain respects from that found in the Amœba and its allies. In the present division the protoplasm is of a reddish-yellow colour, and possesses considerable elastic and contractile properties, whilst through its substance a cyclosis, or circulation of the included particles or granules appears to be incessantly carried on. The pseudopodia are, further, of greater relative length than in other Rhizopoda, the free extremities of these organs in many cases uniting to form a reticulated or network structure.

The shells exhibit in many instances great beauty of structure and design, the geometrical regularity of form being at once remarkable and striking. So far as intimate structure is concerned, the shells or "tests" of Foraminifera consist, in the majority of instances, of carbonate of lime, but in other cases the "test" may be merely arenaceous or membranous, consisting of particles of sand imbedded in a membranous envelope.

Two types of conformation are found in the Foraminiferous shells. In the first type the shell consists of but a single chamber, the shell being thus simple, and the division known as the *Monothalamous*, or "single-chambered" Foraminifera. In the *Polythalamia*, or "many-chambered," Foraminifera, forming the second division, the shell is compound, and consists of a series of chambers arranged spirally or otherwise, and communicating with each other. The development of the Polythalamia takes place by a process analogous to gemmation or budding, the organism in its earlier stages consisting of a simple and single segment, the succeeding chambers and segments being

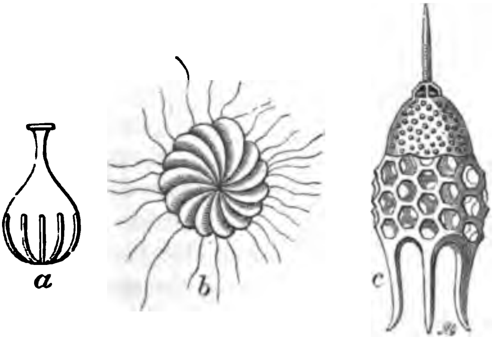


Fig. 4. FORAMINIFERA AND RADIOLARIA.

a, *Lagena striata*; b, *Polystomella crispa*, with pseudopodia; c, *Podocyrtis Schomburgkii*, a Radiolarian.

developed in various axes from this primary mass, to form the compound organism. The *Lagena*, or "flask-animalcule" (Fig. 4, *a*), may be cited as representing the Monothalamia, whilst the *Polystomella* (Fig. 4, *b*) presents a typical example of the Polythalamia; the pseudopodia, in the former instance, being protruded from the single anterior aperture of the shell, whilst, in the latter case, the foramina perforate the walls generally of the divisions or chambers of the shell.

Order (*c*) *Radiolaria.*—The Radiolaria differ from the members of the previous division, in that their shells are composed of siliceous or flinty matter, instead of lime, as in the foregoing group. The pseudopodia of the Radiolaria, in addition, appear to be modified in form and construction, these organs presenting a stiff and rayed conformation, and being in many cases supported on siliceous spines. The *Podocyrtis* (Fig. 4, *c*) represents the present order, the relations of which have as yet been but imperfectly investigated. Viewed distributionally, and in the twofold aspect of space and time, the Foraminifera and Radiolaria present for consideration many features of great interest and importance. Recent deep-sea explorations show that the bed of the ocean is very generally covered by a thick layer of Foraminiferous shells, containing living organisms. This fact serves to correct the generally-received notion that life could not exist in such great depths of water, and further tends to confirm, in a remarkable manner, the geological history of these forms; since the cretaceous rocks and chalk formations of our globe are composed almost entirely of Foraminiferous shells, which must have formed, according to geological interpretation, a layer of great thickness in the bed of an ancient ocean, this layer being deposited, in past ages, exactly as we find the oceanic ooze of Foraminiferous organisms to be deposited in the present day. Whilst the Foraminifera seem to exist in the lower depths of the ocean, the Radiolaria appear to live near the surface of the water, the shells of these latter forms falling in turn to the lower depths, to mingle with the remains of their nearly-related allies. Of ancient forms, the most familiar is the Numulite, so named from its coin-like appearance; and the *Eozoon Canadense*, found in the Laurentian rocks of Canada, and supposed to be the oldest of fossil organisms, is believed to be a Foraminifer, possessing evident relations with certain living and existing forms.

Class III. SPONGIDA.—If a living Sponge be examined, we shall find it to be coated externally, and lined internally, with the soft glairy flesh or sarcode of which the bodies of the Protozoa are composed. The Sponge, familiarly known as such, is thus merely the fibrous framework, or skeleton, which served to support the soft sarcodic and living matter. Morphologically viewed, a Sponge may be considered as a "massing together of Amœba-like animals," the Amœba-like particles each containing a nucleus, and being united together to form "a continuous lamellar membrane." The skeleton or framework of the Sponge consists of two distinct elements, the relation of the two being, however, apparent on close examination only. The first element is represented by the fibrous substance familiarly known as Sponge, which is composed of "keratode," a substance closely resembling horn in composition. The second element consists of "spicula," or needle-like bodies of flint or lime, serving, by their interlacing, to strengthen and support the fibrous framework. These spicula present a great variety of forms, some of which are represented in Fig. 5 (*a*, *b*, *c*, *d*, *e*). In several living Sponges, but principally in extinct and fossil forms, the fibrous framework gives place to, and is represented by, a calcareous or siliceous skeleton, the conformation of which, in fossil specimens, can frequently be determined with great accuracy.

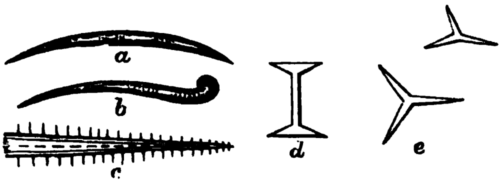


Fig. 5. SPICULA OF SPONGE.

a, *b*, *c*, Siliceous spicula of *Halichondria*; *d*, Spiculum of *Spongilla*; *e*, Triradiate calcareous spicula of *Grantia*.

Sponges, for a lengthened period, were regarded as vegetables, and it is only within recent date that the true animal nature of these organisms has been definitely ascertained. The chief point to which attention has been directed in the examination of the Sponges, is the series of phenomena to which the collective term of "circulation in the Sponge," has been given. On examining any ordinary Sponge, two sets or kinds of apertures can readily be distinguished; a series of larger apertures, comparatively few in number, as compared with the second series of minute holes, which stud over every part of the Sponge. To the larger apertures the term "oscula" is applied, whilst the smaller holes are known as "pores." It is important to distinguish between these apertures, as the functions of each, in the phenomena about to be described, differ most materially. On viewing a living Sponge by the aid of the microscope, a constant circulation of water is perceived to be carried on in the organism. The course of the circulation is as follows:—By the smaller apertures or pores (Fig. 6, *b b*) water is being constantly inhaled, whilst from the larger apertures or "oscula" (Fig. 6, *d*) currents are as incessantly being exhaled. The pores are thus "inhalent," or afferent orifices, the oscula being

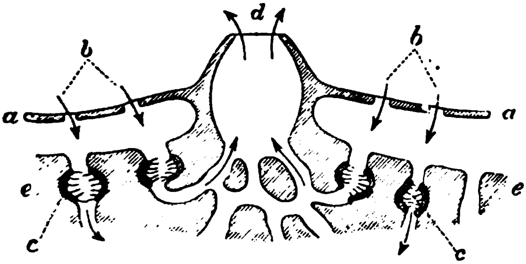


Fig. 6. DIAGRAMMATIC SECTION OF FRESH-WATER SPONGE (*Spongilla*), (after Huxley).

a a, Superficial layer; *b b*, Pores; *c c*, Ciliated chambers; *d*, an osculum; *e*, deeper substance of Sponge. The arrows indicate the direction of the currents.

exhalent, or efferent apertures. The water admitted by the pores permeates the entire system, being conveyed throughout the organism by the intercellular and branching canals which ramify within the Sponge. The mechanism by which the force for carrying on the circulatory movements is supplied, consists in collections of vibratile cilia, or small eyelash-like filaments (Fig. 6, *c c*), contained in circular chambers excavated in the lining membrane of the canals of the deeper substance (Fig. 6, *e*) of the Sponge. By the constant action in one direction of those filaments—namely, towards the oscula—the water is driven from the pores in the direction of the excurrent system of canals, which terminate in oscula; and by the same movement fresh water is as incessantly drawn in through the pores. Nutrient material is thus conveyed through the entire system, and the effete matter is thus also excreted, this latter phase, and indeed the entire series of actions, subserving in a manner the function of respiration, or of a nearly analogous process.

The morphological relations of the vibratile cilia are exceedingly interesting, inasmuch as these filaments appear to consist of the lash-like appendages of the individual sponge particles, or Amœba-like masses, which thus unite together in definite series to form the circulatory apparatus. To a certain extent the circulatory action appears to be a voluntary one, the oscula being closed at the will of the organism, whilst the pores are to a greater degree still under the control of the animal.

Reproduction in Sponges may take place (*a*) asexually, by the development during the winter season of seeds or "gemmules," containing a mass of sponge-particles, which in the spring time are liberated from the seed, and develop into the adult Spongilla; or small ciliated reproductive bodies, or "spores," may be discharged from the oscula with the currents of effete water, these particles leading for a time a free and independent existence, and then finally rooting themselves to some fixed object, and developing the sponge-like form and structure; or, we may have a (*b*) sexual mode of reproduction, in which certain sponge-particles develop by the aid of other particles into ova, these ova becoming segmented as before, and giving rise to ciliated masses, which finally grow into Sponges, resembling those from which they originated. Exhibiting thus a complex structure, and showing decided affinities to the animal series, Sponges have rightly been classed with that division of organic beings. "Now that we know," says Huxley, "the whole cycle of the life of the Sponges, and the characters which may be demonstrated to be common to the whole of this important and remarkable class, I do not think any one who is acquainted with the organisation or the functions of plants, will be inclined to admit that the *Spongida* have the slightest real affinity with any division of the vegetable kingdom."

Class IV. INFUSORIA.—The *Infusoria* present us with an advance on the ordinary Protozoic structure of the preceding groups. The specialisation of a particular part of the body-wall to form a mouth, the consolidation of the body-substance generally, and the increased distinction of even the elementary organs found in these animals, form characteristic points in the advanced organisation of the group. The special and distinctive feature of the class is the incapability of these forms to emit "pseudopodia," together with the universal possession by them of vibratile cilia or filaments, performing a locomotive function, and aiding in the nutritive process also.

The term Infusoria originates in the fact that these animalcules are ordinarily found wherever organic matter in a state of decay is present, and notably in *infusions* of vegetable and animal substances. Thus an infusion of hay, of tea, of leaves, or other vegetable matter being made, and allowed to stand for a longer or shorter period of time, will, on examination, under ordinary circumstances, be found to teem with living forms, of which the most numerous and characteristic are the animalcules included in the present class. To this phenomenon the older philosophers gave the name of "spontaneous generation," a doctrine revived in modern days under the term "Heterogeny;" and the main element in which may be briefly stated as implied in the belief that the animalcules in the infusion were produced spontaneously from the fluid, or without the existence of parent-germs or organisms. The opposers of this view, scientifically known as "panspermists," seek in the air, and in the substances mechanically suspended in and conveyed by that medium, the true explanation of the production of Infusorial animalcules in organic infusions. Recent researches would seem to afford strong evidence in favour of this latter and more feasible theory, which possesses, at the same time, the additional merit of at least endeavouring to satisfactorily and sensibly account for the production of these forms. Modifications of this broad theory are continually being brought forward, but, in the main, the grounds of belief rest on the supposition that the germs or seeds of living bodies are carried by the air, and that these germs, finding a suitable medium in the decaying infusion, there develop the forms of life of which they are the embryos. The laws which regulate the production and conservation of living matter have yet to be fully investigated, but there can be little doubt that in the so-called "germ-theory," we have the foreshadowing, in hypothesis, of what after-research will prove to be established fact.

The general morphology of the class may best be studied by the examination of a typical form, such as that of *Paramœcium*, familiarly known as the "slipper animalcule," and of which a diagrammatic representation is seen at Fig. 7, A. The body is somewhat of oval shape, the margin being formed by a structureless but firm membrane (cuticle), the outer edge of which is fringed with the delicate vibratile filaments to which the term "cilia" is applied. Within the "cuticle," the body-substance exhibits a firm layer of structure, to which the term "cortical layer" has been given, whilst this encloses in turn the central and softer sarcode. Three layers of substance are thus distinguished in the structure and tissues of the body. At one point (*o*) the mouth is seen, and from this, formed, as it were, by an involution of the external boundary-membrane, we have continued a tube-like canal, representing an œsophagus or gullet, but which gradually and shortly merges in one with, and becomes lost in, the general and central protoplasm of the body. Differentiation has proceeded thus far, a mouth and rudimentary gullet being specialised, but here the process stops short, the specialisation reaching in the present instance no higher grade of development. The "cortical layer" contains the only remaining structures which merit our attention. The first of these is constituted by the nucleus

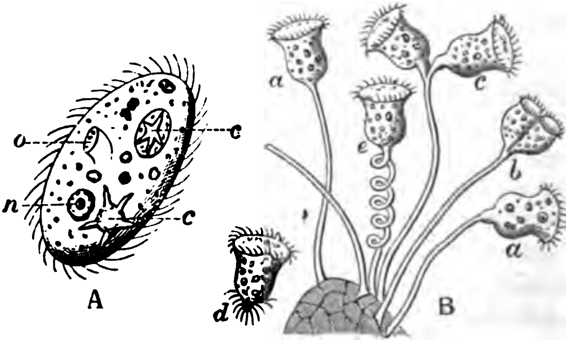


Fig. 7. Morphology of Infusoria.

A, Diagram of *Paramœcium:* *o*, mouth, continued into the rudimentary gullet; *n*, nucleus, with nucleolus; *c c*, contractile vesicles, showing radiating processes. B, Group of *Vorticellæ:* *a a*, adult Vorticellæ; *b*, an animalcule undergoing lateral extension; *c*, further stage of *b*, two heads being borne on the same stalk; *d*, detached cup, with posterior cilia; *e*, Vorticella contracted on its stalk.

(*n*), which may have a nucleolus attached to its external surface. The nucleus, and its attached nucleolus, appear in the Infusoria to be intimately connected with, if not essentially to represent, the reproductive system. The second organ consists of the "contractile vesicles" (*c c*), which, as in the Amœba, perform the office of circulatory organs; the "vesicles" of the Infusoria, however, exhibiting what must be considered an advance on the structure of those of the Amœba, in that, from the "vesicles" in the Infusoria, certain radiating tubes or vessels are occasionally seen to proceed. If the existence of these vessels—and their existence is generally admitted—be admitted, there seems every reason to suppose that they represent a rudimentary circulatory apparatus, and correspond in function, or are analogous to the blood-vessels of higher forms. The clear spaces or "vacuoles," observed in the neighbourhood of food-particles which are undergoing solution, are to be noticed in the present instance. Ehrenberg, the great German microscopist, to whom we are indebted for at least the greater part of our knowledge regarding these creatures, fed these animalcules on coloured foods, as we have previously described; and observing that the food-particles, after passing through the gullet, were deposited in various situations throughout the substance of the body, he concluded, from seeing the "vacuole" around each food-particle, that the little masses of nutriment represented so many distinct stomachs. From this supposed structure he gave to the Infusoria the name

"Polygastrica," or "many-stomached," animalcules. As now known, the "stomachs" of Ehrenberg are merely the "vacuoles" or spaces which indefinitely, and without any regard to position or relation of parts, form around the particles of nutriment deposited in the substance of the body. A brightly-coloured particle, generally of a red colour, occurs in almost all Infusoria. It is termed the pigment spot, but its function is quite undetermined. Locomotion in the Infusoria is effected by the vibratile cilia, the currents created by these filaments also serving to attract particles of food towards the oral aperture.

Reproduction may take place in the Infusoria in one or other of three distinct modes. The first of these processes is by (*a*) simple fission, an animalcule being seen to divide into two parts, each part swimming away freely, to develop cilia, and start life as an independent organism. Thus, in Vorticella, a stalked Infusorian (Fig. 7, B), the bell-shaped calyx is seen at *b* to extend itself laterally, this process continuing until, as seen at *c*, we have two cups borne on the one stalk, the primary cup having become divided into two portions. Soon one or both of these newly-developed forms become detached, and fresh cilia are developed on the inferior or stalk extremity of the bell-shaped disc, the cup now swimming freely about in the surrounding water (*d*). After continuing in this independent and unattached condition for a certain period, the detached cup fixes itself to some object, and, with the development of a stalk from the point of attachment, the adult and perfect form of the organism (*a a*) is again assumed. In the second process (*b*), by "*gemmation*" or "*budding*," a bud is produced from near the attached extremity of such a form as Vorticella, this bud becoming quickly provided with cilia, and detaching itself, swims in the water as a free organism, to attach itself in time, and to develop a stalk, as in the fissiparous mode of reproduction. In the third and last form of the reproductive process (*c*), by "*sexual multiplication*," ova are produced through the agency of the nucleus and nucleolus, the former being supposed to represent the ovary or female element, the latter representing the testes or male reproductive organ. The altered nucleus enlarges, becomes rounded, undergoes segmentation, ruptures, and gives origin to ciliated germs, which ultimately develop into true and adult Infusorial forms.

Classification.—The Infusoria are divided by the number and disposition of the cilia into three orders:—

Order 1. *Ciliata.*—Ex. *Vorticella*, *Paramœcium*, etc.
Order 2. *Flagellata.*—Ex. *Peranema.*
Order 3. *Suctoria.*—Ex. *Acineta.*

Order 1. *Ciliata.*—The Ciliate Infusorians are by far the most numerous. They are characterised by the disposition of cilia generally over the body. Of this group, *Paramœcium* (Fig. 7, A), *Vorticella* (Fig. 7, B), and *Stentor*, or trumpet animalcule (Fig. 8, *a*), and *Vaginicola* (Fig. 8, *c*), may be cited as typical representatives.

Vorticella represents the fixed Infusoria, the body in this form consisting of a bell-shaped calyx, which is supported on a contractile stem. The animal, when alarmed, has the power of coiling itself on its stalk (Fig. 7, *e*), a movement effected by the agency of a muscular or contractile fibre, with which the stem is furnished. The edge of the disc is seen to be fringed with cilia. In the case of *Stentor*, the animal possesses the power of detaching itself from the object to which it is fixed, and of again fixing itself at will. In *Vaginicola* is represented a fixed form, enclosed in a membranous sheath, from which the technical name of the creature is derived, and into which the animal can retract itself at will.

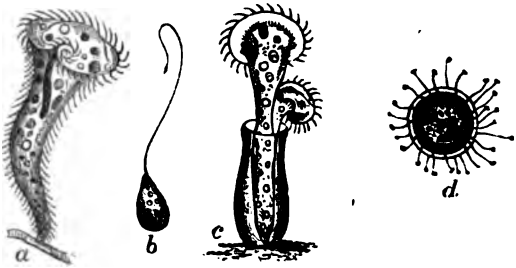


Fig. 8. INFUSORIA.

a, *Stentor Mulleri*, with food-particles, nucleus, etc.; *b*, *Peranema globulosa*, a Flagellate Infusorian; *c*, *Vaginicola crystallina*; *d*, *Acineta*, a Suctorial Infusorian.

Order 2. *Flagellata.*—The members of this group are characterised by the presence of "flagella," or lash-like appendages, by which locomotion is effected; cilia, in some instances, being found present in addition to these "flagella." *Peranema* (Fig. 8, *b*) will serve to illustrate this order.

Order 3. *Suctoria.*—The forms included within this division are of somewhat undetermined nature, their relations to the preceding groups being as yet indefinite. The *Acineta* (Fig. 8, *d*) may be selected as representing the group, the members of which are characterised by the possession—as implied by the term Suctoria—of suctorial tubes, these supplying the place of the cilia, which in the present instance are wanting. By some observers *Acineta* is considered to be but a transitionary stage in the development of Vorticella.

Closely allied to the Flagellate Infusoria is the *Noctiluca miliaris* (Fig. 9), to the agency of which the phenomenon known as the phosphorescence of the sea is said to be in great measure due. Each movement of the vessel in the dark causes a strange phosphorescent gleam to appear on the surface of the water; and even the gentlest ripple, caused by a passing breeze, may send the same strange luminosity shooting athwart the surface of the sea. The immediate cause of this strange property is said to reside in some electrical or analogous force, excited, as we know it is in the higher forms, by and through the agency of the nervous system.

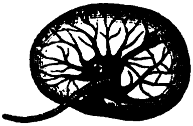


Fig. 9.
Noctiluca miliaris.

CLASSIFICATION OF PROTOZOA.

CLASS I. GREGARINIDA. Ex. *Gregarina.*

CLASS II. RHIZOPODA.
- Order (a) *Amœbea.* Ex. *Amœba.*
- Order (b) *Foraminifera.* Ex. *Polystomella.*
- Order (c) *Radiolaria.* Ex. *Podocyrtis.*

CLASS III. SPONGIDA. Ex. *Spongilla.*

CLASS IV. INFUSORIA.
- Order (a) *Ciliata.* Ex. *Paramœcium.*
- Order (b) *Flagellata.* Ex. *Peranema.*
- Order (c) *Suctoria.* Ex. *Acineta.*

CHAPTER IV.

CŒLENTERATA.

General Characters—Classification—Characters of the Hydrozoa —Orders of Hydrozoa.

THE *Cœlenterata* present a marked advance on Protozoic structure, and the consideration of this sub-kingdom leads us to deal with increased specialisation both of organs and tissues. The Cœlenterate animals represent the *Radiate* division of the older naturalists; but from the limits of the newer division, many forms, classified under the Radiate type, have been removed and placed in another sub-kingdom of recent construction—the Echinozoa.

The term Cœlenterata is derived from the consideration of a special feature in the morphology of the group, the signification of the name implying that, as in the higher division of the order, the digestive sac and general cavity of the body are in free communication with each other. A definite "somatic," or body-cavity always exists, the symmetry being typically of the radial kind, united with bilateralism. The body-tissues of the Cœlenterata consist fundamentally of two layers or membranes, the primitive simplicity of which may, however, become more highly specialised, muscular fibres being differentiated in the higher members of the group. To the outer or more external of these membranes, the term "ectoderm" is applied, the inner layer being named the "endoderm" (Fig. 10, 1, *c d*).

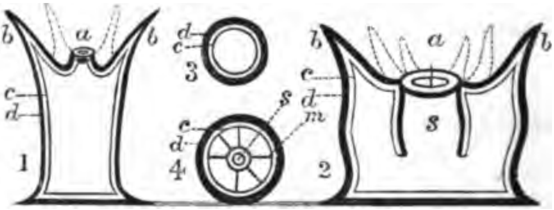


Fig. 10. MORPHOLOGY OF CŒLENTERATA.

Vertical section of Hydrozoon. *a*, mouth; *b*, tentacles; *c*, endoderm; *d*, ectoderm. 2. Vertical section of Actinozoon (the letters refer to the corresponding parts in each figure); *s*, stomach-sac. 3. Transverse section of Hydrozoon. 4. Transverse section of Actinozoon; *m*, mesentery.

The vibratile filaments, known as "cilia," are found on both ectoderm and endoderm—the former being most generally furnished with these organs. In the majority of Cœlenterata forms, numerous small vesicles, termed "cnidæ," or "thread-cells," exist; the function of these bodies is undoubtedly that of offensive organs, serving to aid the prehensile apparatus in the capture of prey; the stinging, or urticating powers of many Cœlenterata being due to the presence of these "cnidæ." No defined vascular system exists in the Cœlenterata; and in a few of the higher forms only can a rudimentary nervous system be discerned.

In habits the Cœlenterata are aquatic, the great majority of these animals inhabiting the ocean.

Classification.—The Cœlenterata are divided into two classes :—

Class I.—Hydrozoa.
Class II.—Actinozoa.

The chief distinctive feature between these divisions is found in the possession of a distinct stomach-sac by the Actinozoa, and in its absence in the Hydrozoa. A vertical section of the body of a Hydrozoon, as depicted in Figure 10, 1, shows a simple body-cavity, the walls of which are formed by the double membrane before mentioned. A similar section of an Actinozoon, however (Fig. 10, 2), reveals the presence of a distinct stomach-sac (*s*), differentiated from the walls of the body, with which it is connected by a series of radiating membranous plates, termed "lamellæ," or "mesenteries," to the faces of which the reproductive organs are attached. In the Hydrozoa, on the contrary, the reproductive organs are external. Transverse sections of these forms exhibit the morphology of each in still plainer manner. In such a section as at 3, the body of the Hydrozoon appears as a simple tube ; whilst in the section of the Actinozoon (4) we have a double tube—the outer circle corresponding to the section of the body-wall, whilst the inner and contained tube (*s*) represents the section of the stomach-sac. In this latter section, also, the radiating mesenteries (*m*) are also brought into view.

Class I. Hydrozoa.—The Hydrozoa are accordingly defined as Cœlenterata, in which a digestive sac is not specialised from the walls of the body-cavity. The typical animal is the Hydra (Fig. 11, 1, 2, 3), a common fresh-water polype of minute size, and which is found adhering to the stems of duckweed and other aquatic plants. It is of slender cylindrical form, the mouth being situated at the "distal," or free extremity of the body, the term "proximal" being applied to the attached end. The mouth is surrounded by a circle of tentacles, or prehensile organs, which may be short and stunted, or of a considerable length, according to the species examined. In the long-armed species (*Hydra fusca*, Fig. 11, 2), the tentacles exceed greatly the length of the body; whilst in the Green Hydra (*Hydra viridis*, Fig. 11, 1) these organs are short and contracted. By means of the tentacles, the animalcules and minute organisms on which the creature feeds are encircled, and dragged towards the

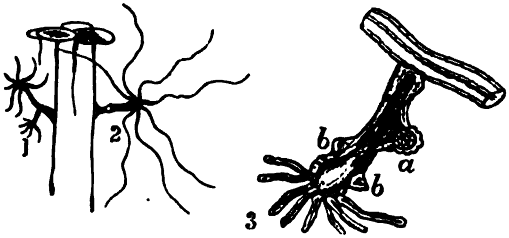


Fig. 11. Hydridæ.

1. *Hydra viridis*, attached to a stem of duckweed; a young polype is seen budding from the side of the parent organism. 2. *Hydra fusca*, the long-armed Hydra. 3. Enlarged figure of *Hydra viridis*, showing tentacles, ovum (*a*), and spermatozoic receptacles (*b b*).

cavity of the mouth—a function in the performance of which they are considerably aided by the "cnidæ," or "thread-cells" (Fig. 12), with which they are abundantly provided, and which form so characteristic a feature of the group. Each thread-cell consists of a minute oval vesicle, bounded by distinct walls, containing fluid, and having coiled up in its interior an attached thread, or "ecthoræum." Under pressure, or when subjected to irritation, the contained fluid escapes, the filament or "ecthoræum" being projected towards the offending body. In some forms, as exemplified by the common Hydra, the thread-cell of whose body is represented at *a* (Fig. 12), the base or attached point of the filament is armed with minute

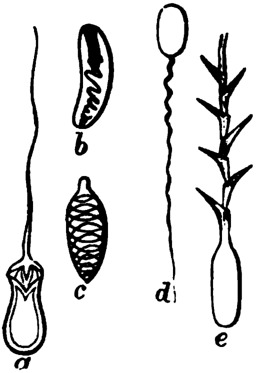


Fig. 12. CNIDÆ (after Gosse).

a, Thread-cell of *Hydra vulgaris*, with ecthoræum protruded; *b*, thread-cell of *Carophyllia Smithii*; *c*, thread-cell of *Corynactis Allmani*; *d*, thread-cell of *Willsia stellata*; *e*, thread-cell of *Actinia crassicornis*.

spines; whilst in other cases (Fig. 12, *e*) the thread itself possesses a barbed or serrated margin. In all probability some chemical or poisonous action is produced by the fluid of the cnidæ, whilst the threads may form the means for its introduction within the body of the captured prey.

The mouth, as we have seen, leads directly into the somatic or body-cavity, which subserves in this instance the function of a digestive sac. The effete products of digestion are expelled by the mouth, no distinct anal aperture being present.

Although attached to fixed objects by a defined "hydrorhiza," or root, the Hydra possesses the power of detaching itself at will, and of again fixing itself as before, locomotion being effected by means of the tentacles, aided by the hydrorhiza or attached disc, the creature progressing by a series of leech-like movements, applying the tentacles and disc alternately to the surface over which it is proceeding.

The last feature worthy of notice in the economy of the Hydra is the remarkable power it possesses of surviving after the infliction of what to most animals would prove fatal injury. Trembley of Geneva, about the middle of last century, performed many experiments on the Hydra, with a view to ascertain the animal's reparative powers; and he found that an individual polype might be divided vertically or transversely, without at all inconveniencing the creature, a new and perfect polype being developed from each portion of the divided body. Even when turned inside out, like the sleeve of a coat, and the inner membrane thus exposed to form the outer layer, the polype appeared to be uninjured by the operation, as it shortly resumed all the functions of its life, adapting itself in the most perfect manner to the exigencies of its new position.

Reproduction in the Hydrozoa may take place after one or other of two distinct fashions, but it must at the same time be borne in mind that various and complicated modifications of those primary processes exist. The first mode in which reproduction may be effected is by a simple process of "gemmation" or budding. The common Hydra, during the warmer months of the year, illustrates this first process. A little tubercle is first observed to form on the side of the parent-polype, and this increases in size, developing in time a mouth and tentacles at its free extremity, and finally constituting a young Hydra, growing from the side of the parent organism (Fig. 11, 1). The young animal, so produced, may continue attached to the parent-body for a period more or less long, and this primitive bud may produce from its body buds which will in turn develop into Hydræ like unto itself; so that three, or even more generations of polypes, may be thus observed adhering and connected to one another. While in this connected state free communication exists between the body-cavities of the various polypes, but this communication closes before the buds become detached, to live a separate existence—an event which happens sooner or later in their life history. The second reproductive process, in which the sexual elements take part, is intricate in all its bearings, and has yet to be more fully investigated; still it serves in a manner, at once strange and evident, to connect together the various and diverse groups and forms into which the class has been divided. At the one morphological extreme we have in the Hydrozoa the true polype-like forms, such as *Sertularia* (Fig. 16), consisting of a common trunk or stem, serving to unite the various polypes borne by the branched extremities of the axis; we have thus a compound organism formed, the ordinary Zoophytes serving as typical examples of this variety of form. At the other extreme are placed the Medusiform Hydrozoa, of which the *Medusa* or Jelly-fish (Fig. 17, 1) may be taken as a typical representative. These latter forms are free and oceanic in their habits, and thus apparently differ widely from the polype-like Hydrozoa. Between these extremes many intermediate forms undoubtedly exist, but the consideration of the reproductive process serves in a very evident manner to establish certain relations between the members of the group. The polype-like forms increase by budding like the Hydra, but the buds so produced are permanent, and remain attached, to form the compound organism (Fig. 13, 1). Besides these true and ordinary buds, containing the individual polypes, certain other buds are at intervals developed in turn from the external walls of the organism. These buds appertain to the reproductive function, and are termed "gonophores" (Fig. 13, 2, *a*, *b*, *c*, and 16, *d*). In some instances these gonophores contain the male reproductive elements, whilst others are devoted to the development of the female element, these latter containing ova. The process of reproduction by the second process, and through the agency of these peculiar reproductive buds, may thus be briefly described. Having attained the acme of their development, the gonophores rupture (Fig. 13, 3, 4), and their contents escape into the surrounding water as minute, freely-swimming, ciliated masses (Fig. 13, 5). The little embryo may, in some cases, continue in this form to live for a time an independent and unattached existence, whilst in other instances it appears to assume the form of a veritable Medusa (Fig. 17, 1), furnished with the characteristic bell-shaped swimming disc, by the alternate contraction and expansion of which it

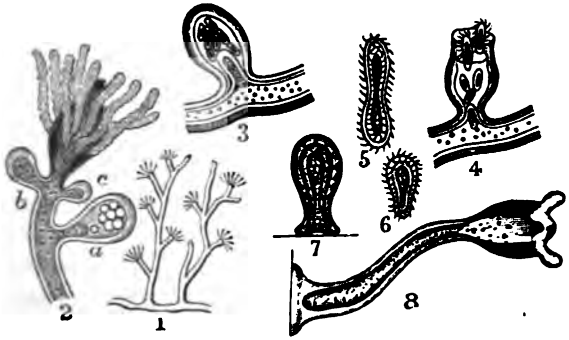


Fig. 13. Development of Corynidæ *(Cordylophora lacustris)*, (after Allman).

1. Hydrosoma of *Cordylophora*. 2. Portion of the same magnified, and showing three gonophores, that at *a* being the most advanced, and containing ova. 3. Gonophore, greatly magnified, with contained embryos. 4. Gonophore ruptured, with embryos escaping. 5. Free-swimming ciliated embryo. 6. The same, having assumed a pyriform or pear-shaped figure. 7. Attached condition of the same. 8. Primary polypite developed from the attached embryo (7).

propels itself through the water. Many forms, at one time classified with the Medusidæ, have been found, on a careful examination of their further development, to be merely the free generative buds of other Hydrozoa. After thus existing, usually for a definite period, the free ciliated organism enters upon the final stage of its developmental process. It assumes a pyriform figure (Fig. 13, 6), and then attaching itself to some fixed object (7), develops at its free or distal extremity a mouth and tentacles, and thus resembles a hydra-like form in appearance (Fig. 13, 8). As this secondary development advances, the isolated organism grows apace, and in time, by a process of gemmation or budding, a compound organism is produced, like unto that from which the ciliated embryo first sprang. Such may be regarded as an outline of the reproductive process in the Hydrozoa, modifications of which—and frequently to a very considerable extent—occur throughout the various divisions of the group. To the above series of phenomena the term "alternation of generations" has been applied. The correctness or application of the term need not here be discussed, but, as correctly understood, the processes involved under the above term show that each generation alternates with that which succeeds it; in other words, that the reproductive elements of one form become developed into a series of organisms entirely different from the producing stock, whilst from the organisms thus produced forms resembling the original individuals are evolved. To use the homely simile of Chamisso, the offspring in either case resemble not the parents but the grand-parents. The generative Zoöids of the compound polype resemble, in their first stage of development, not the parent-organism, but bear a close resemblance to free-swimming Medusids; whilst it is only after the reproductive process in this second form has been completed, that the young again resemble the polype-like stock, and form a continuous branched organism.

The terms "individual," and "zoöid," as used in zoological science, therefore, bear a distinct and important signification. Thus, in compound polypes (such as Sertularia), the entire organism constitutes the zoological individual, the separate polypes representing the included "Zoöids." And in the reproductive process just described, two distinct elements are perceived. The first of these is represented by the sexless or polype-bearing organism, which can increase by no other process save "gemmation," and the existence of which is devoted to the nutrition and growth of the form. The second element is represented by the generative bud, capable of reproducing the species through the evolution of a seemingly different form, and on the performance of the reproductive function the whole energies of this latter form are brought to bear.

Classification.—The class Hydrozoa is divided into seven orders—

Order 1. *Hydridæ.* Ex. Hydra.
Order 2. *Corynidæ.* Ex. Cordylophora.
Order 3. *Sertularidæ.* Ex. Sertularia.

Order 4. *Calycophoridæ.* Ex. Diphyes.
Order 5. *Physophoridæ.* Ex. Vellela.
Order 6. *Medusidæ.* Ex. Medusa.
Order 7. *Lucernaridæ.* Ex. Lucernaria.

In describing the morphology of the Hydrozoa, a technical terminology is employed, and the explanation of the more important terms may not, at the present stage, be out of place. In the accompanying figure (which we have taken the liberty of copying from Professor Greene's able work on the Cœlenterata), the general morphology and relations of the various groups are shown. The entire body of a Hydrozoon, simple or compound, is termed the "hydrosoma," its fixed or proximal extremity being known as the "hydrorhiza." To the alimentary region, or digestive system, the term "polypite" (Fig. 14, *p*) is applied; whilst to the connecting medium or common trunk of the compound forms, the name of "cœnosarc" (*c*) is given. In several forms, exemplified by the *Sertularidæ* alone, the "cœnosarc" gives origin to horny cups, in which the "polypites" are contained, and to which the term "hydrothecæ" (*h*) is applied. The nutritive element of the Hydrozoon is known by the collective appellation of "trophosome," whilst the generative, or reproductive element, is accordingly denominated the "gonosome." Thus, the hydrosoma of Sertularia, with ordinary polypites, constitutes the "trophosome;" the generative buds, which are likewise produced on the hydrosoma, representing the "gonosome."

Order 1. *Hydridæ.*—This order includes but one genus, that of Hydra (Fig. 11, 1, 2, 3), the structure of which has been previously described. The hydrosoma is simple, consisting of but a single polypite. The Hydridæ inhabit fresh water, the most familiar species being the *H. viridis*, *H. vulgaris*, and *H. fusca.*

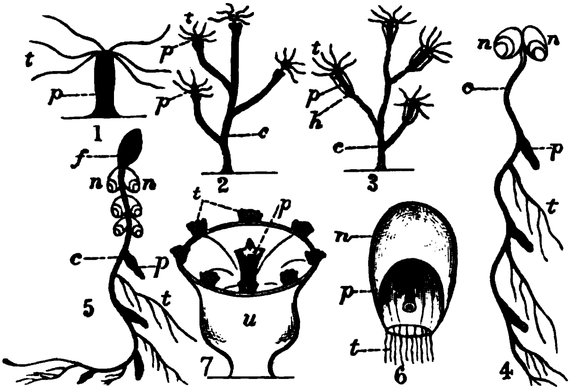


Fig. 14. Morphology of Hydrozoa (after Greene.)

1. *Hydrid;* 2. *Corynid;* 3. *Sertularid;* 4. *Calycophorid;* 5. *Physophorid;* 6. *Medusid;* 7. *Lucernarid.* *c*, cœnosarc; *f*, pneumatophore, or float; *h*, hydrotheca; *n*, nectocalyx; *p*, polypite; *t*, tentacles; *u*, umbrella.

Order 2. *Corynidæ.*—The forms included under this head are almost exclusively marine. The Corynidæ exist as simple organisms, as in *Tubularia* (Fig. 15, *a*), or compound, as in *Cordylophora*, which is the only fresh water form (Fig. 13, 1, 2); the branched cœnosarc with the polypites being well exemplified in the present instance. The development of Cordylophora, previously described, is depicted in Fig. 13.

Order 3. *Sertularidæ.*—This order is represented by the well-known polypes termed "sea-firs," or *Sertulariæ* (Fig. 14, 3), and which are found attached to the broad fronds of tangle and sea-weed round all our coasts.

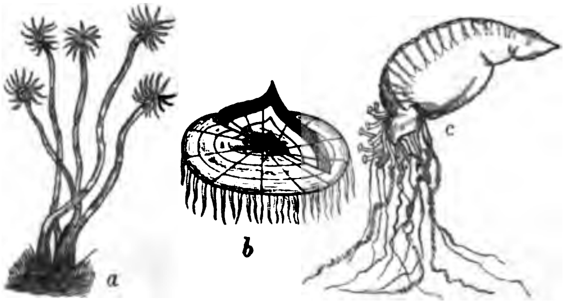


Fig. 15. MORPHOLOGY OF CORYNIDÆ AND PHYSOPHORIDÆ.
a, *Tubularia indivisa*; *b*, *Velella vulgaris* (after Gosse); *c*, *Physalia pelagica* (Gosse).

The hydrosoma is compound, the polypites being enclosed within "hydrothecæ" (Fig. 16, *h*), the possession of which forms a feature characteristic solely of the present order.

Order 4. *Calycophoridæ.*—The "cup-bearing" Hydrozoa, whilst presenting forms which at first sight hardly appear referable to the ordinary type of structure of the class, nevertheless show their analogous structure on closer examination. The hydrosoma is, in the present instance, free and oceanic, the animals floating on the surface of the water by aid of the "nectocalyces," or "swimming-bells," with which the creature is provided (Fig. 14, 4, *n n*). The cœnosarc, as before, supports the polypites with the accompanying tentacles and other organs. The form known as *Diphyes*, found floating on the surface of the warmer seas, and presenting the most beautiful delicacy of structure, typically represents the group.

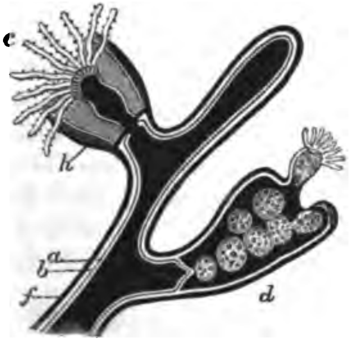


Fig. 16. Diagram of Sertularid.

a, Endoderm; *b*, ectoderm; *c*, polype, showing tentacles and alimentary region; *d*, gonophore, with contained ova; *f*, cœnosarc; *h*, hydrotheca.

Order 5. *Physophoridæ.*—Of this order, the *Velella* (Fig. 15, *b*) and *Physalia* (Fig. 15, *c*), or "Portuguese man-of-war," may be cited as typical examples. As in the preceding group, the forms are free and oceanic in their habits, the proximal extremity of the cœnosarc expanding to form the organ by the agency of which the Physophorid is enabled to float on the surface of the water, and which is known as the "pneumatophore," or "float" (Fig. 14, 5, *f*). The nectocalyces (Fig. 14, 5, *n n*), seen in the previous group, are also present in many Physophoridæ. The tentacles, in many instances, attain a great length, the cœnosarc being, however, but slightly branched throughout the group. In *Physalia*, the pneumatophore attains a considerable size, the appearance of the creature when floating on the water suggesting the familiar name by which this form is known.

In *Velella*, the pneumatophore bears a vertical crest, the cœnosarc, polypites, and additional organs, being concealed by the broadened form of the float.

Order 6. *Medusidæ.*—This order includes the familiar "jelly-fishes," or "sea-blubbers," so frequently cast on our shores by the receding tide. The hydrosoma consists, in the present instance, of but a single nectocalyx (Fig. 17, *m*), from the roof of which the single polypite (*p*) depends; the nectocalyx familiarly representing a bell, the polypite corresponding to its tongue or clapper. The nectocalyx is traversed from its centre to its margin by four radiating canals (*a*), springing from the upper end of the polypite as a central point. These canals, on which the reproductive organs (*r*) are generally developed, open into a circular vessel (*m*),

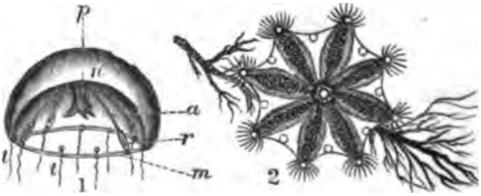


Fig. 17. MEDUSIDÆ AND LUCERNARIDÆ.

1. Figure of *Medusid; a*, radiating canal; *n*, nectocalyx; *m*, marginal canal; *p*, polypite; *r*, reproductive organ; *t t*, tentacles, at the bases of which the "marginal vesicles" are seen. 2. *Lucernaria auricula* attached to seaweed.

which runs round the margin of the disc, the entire apparatus thus constituting a circulatory system. A second and inner "bell," to which the term "velum" is applied, is also present, and is depicted in the accompanying figure.' The tentacles (*t t*) fringe the margin of the nectocalyx, and around the edge of the bell-shaped disc, and situated at the bases of the tentacles, certain bodies, to which the respective names of "otolitic vesicles," and "pigment-spots," or "ocelli," are applied, have been found. These "otolitic vesicles" consist each of an oval cell or cyst, containing particles of solid mineral matter, and to this body the auditory or hearing sense has been assigned, whilst the small masses of coloured matter or pigment have, in like manner, been regarded as rudimentary eyes.

The Medusidæ very generally possess the faculty of producing stinging or urticating sensations, this power, in all probability, residing in the thread-cells with which, in common with most Cœlenterata, they are furnished. Indeed, some of the larger species sting so fiercely, that serious effects have been noticed as resulting from contact with the tentacles. With other organisms, the Medusidæ apparently possess the power of causing the peculiar phenomena before alluded to, and known as the "phosphorescence of the sea."

Order 7. *Lucernaridæ.*—This last order, represented by the *Lucernaria* (Fig. 17, 2), is distinguished by the lower portion of the polypite being modified to form a cup-shaped disc, known as the "umbrella," and which is capable of being folded or expanded at the will of the animal. The hydrorhiza is not permanently attached to fixed objects, but can be detached, and again refixed, as in Hydra itself. The mouth, representing the distal extremity of the polypite, is situated in the centre of the cup-shaped body, the tentacles being arranged in definite series around the margin of the umbrella. Within the cup a series of radiating canals exists, an arrangement resembling in all essential points the similar system in the Medusidæ. The Lucernaria is a small form, occurring around our coasts. It ordinarily attaches itself to sea-weed, etc., detaching itself at pleasure. At 2, Fig. 17, the Lucernaria is depicted in its fully expanded condition. The oceanic forms of Lucernaridæ form large Medusiform bodies, the discs, in some instances, measuring three to four feet in diameter. The *Rhizostomidæ* typically represent the latter forms.

In their development, certain members of this group present characteristic examples of the phenomena to which the term "alternation of generations" has been collectively applied, the ovum freely swimming at first as an oval, flattened, ciliated disc, known as the "Planula" (Fig. 18, *a*). This primitive body next attaches itself to some fixed object (*b*), developing, in turn, a mouth and tentacles, and resembling in all essential points the ordinary Hydra (*c d*), the organism being in this stage known as a "Hydra tuba." In this condition, also, it may give rise to buds, the process of gemmation being carried on as in Hydra. The organism may continue in this stage of its existence for a period extending, in some cases, it is said, over a number of years, the final phases of its existence being ushered in by the transverse marking and division of the hydra-like stem (*e*). The term "Scyphistoma" is applied to this stage of the development, the form, when first observed, being regarded as a new and distinct creature. The transverse markings soon deepen in intensity, the edges of the divisions becoming further notched and serrated (*f*), until the entire organism has been not inaptly compared to "a pile of jagged saucers placed upon one another, and surmounted by a crown of tentacles." In this condition the organism is known as the "Strobila." The tentacles now begin to fall away, and the already divided stem separates into various disc-shaped bodies, or "Ephyræ" (*g*), which swim about freely, and resemble Medusæ so closely, that the free segments were at first

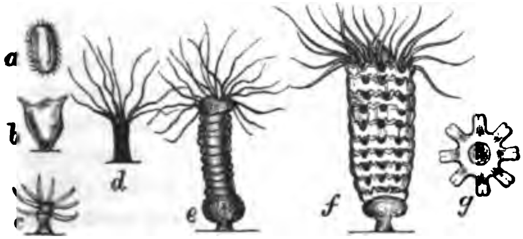


Fig. 18. Development of Lucernaridæ.

a, Free ciliated embryo (or "*planula*); *b*, The same, having attached itself to a fixed object; rudimentary tentacles are seen to be formed; *c*|*d*, "*Hydra tuba*" with tentacles; *e*, Transverse division of stem of *Hydra tuba* ("*Scyphistoma*"); *f*, Further development of *e* ("*Strobila*"); *g*, Detached segment of *f* ("*Ephyra*").

described as a new genus of Medusidæ. After some further changes, however, the "Ephyra" develops the true characters of the Lucernarid, from which the fertilised ovum first sprang.

Graptolidæ.—The Graptolites (Fig. 19, *a b*) represent an extinct group of Hydrozoa, nearly allied in structure to, and possessing relations with, existing Sertularidæ. They form fossils characteristic of the most ancient (Palæozoic) period in our earth's geological history, and their frequent occurrence in the rock-systems of that epoch is indicative of a correspondingly great development of Hydrozoal life in the ancient seas of that period.

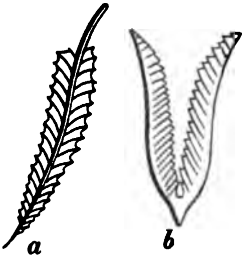


Fig. 19. GRAPTOLIDÆ.
a, Diplograpsus; b, Didymograpsus.

CHAPTER V.

CŒLENTERATA—(*Continued*).

CLASS II. ACTINOZOA.

General Characters—Classification—Zoantharia—Alcyonaria—Rugosa—Ctenophora.

THE Actinozoa, forming the second division of the Cœlenterate sub-kingdom, is represented by the sea-anemones, corals, and allied forms. The Actinia (Fig. 21, *a b*) is selected as the typical representative of the group. A stomach-sac is now found differentiated from the general cavity of the body, this advance in specialisation constituting, as previously noticed, the principal distinctive feature between the Actinozoa and Hydrozoa. The tendency to differentiation of tissues is also noticed in the separation and development of distinct muscular fibres. The thread-cells and cilia found so generally throughout the Hydrozoa are also common to the present group. The Actinia presents a simple enough body for examination, the animal appearing as a shortened cylinder, at the superior or free extremity of which, the mouth, surrounded by numerous tentacles, is situated. The latter organs are placed in alternate rows, and are abundantly supplied with

Order 3. *Rugosa.*

Order 4. *Ctenophora.*

The *Rugosa*, forming an extinct group, are represented by certain corals.

Order 1. *Zoantharia.*—The Zoantharia, generally, are distinguished by having their tentacles and soft parts arranged in multiples of five or six, and by the simplicity of the former organs. The order is divided into three subordinate groups, characterised by the presence or absence of coral structure, and by its variety when present.

Sub-order (*a*). *Zoantharia Malacodermata.*—The "soft-skinned" Zoantharia are typically represented by the *Actinidæ*, or sea-anemones (Fig. 21). No defined coral structure exists in the present instance, the "Actinosoma," or entire organism, consisting—with the exception of the *Zoanthidæ*—of but a single and simple polype.

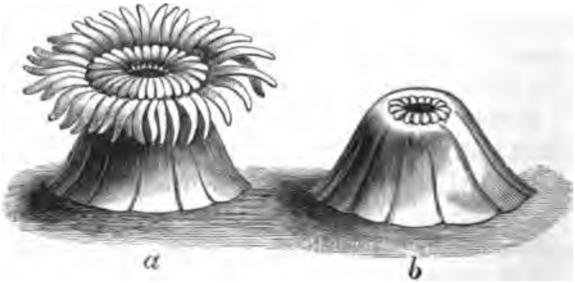


Fig. 21. Actinia Mesembryanthemum.

The Common Sea-Anemone. *a*, Expanded; *b*, contracted.

Of the *Actinidæ* many examples are found on the British coasts, their beautiful appearance, when expanded, suggesting the popular name of "sea-flowers." When contracted, and the tentacles drawn within the oral aperture, the animal presents a somewhat conical mass. The *Zoanthidæ*, representing another family, resemble small anemones; the actinosoma in the latter case being compound, and consisting of a few polypes, united by a common basal cœnosarc.

Sub-order (*b*) *Zoantharia sclerodermata.*—As the term "hard-skinned" implies, the members of this division are characterised by the possession of a coral structure, to the nature and relations of which we must, in the next place, direct attention. If we suppose the sea-anemone to possess the power of secreting calcareous or limy material, which in some cases would appear as an external or exo-skeleton, and in other instances as an internal or endo-skeleton; and if we further suppose that such a creature could increase by gemmation or budding, like the Hydra, the buds or polypes so produced remaining to form permanent and essential parts of the organism, we shall have a somewhat rough and ready, but sufficiently clear, idea of the nature and relations of the coral-producing polypes. The term "corallum," or "coral," is employed to designate this structure, of which two principal varieties are to be distinguished. The first, or "Sclerodermic" variety, is secreted *within* the organism, and is thus a true "tissue-secretion;" the "Sclerobasic," forming the second variety, on the contrary, is secreted by the outer skin, or investing membrane of the body, and is thus somewhat analogous to an exo-skeleton, such as the shell of crustacea.

As the Sclerodermic variety constitutes the typical kind of corallum, and as its description involves a consideration of the most important and essential features of the structure, attention must, in the first place, be directed to this variety.

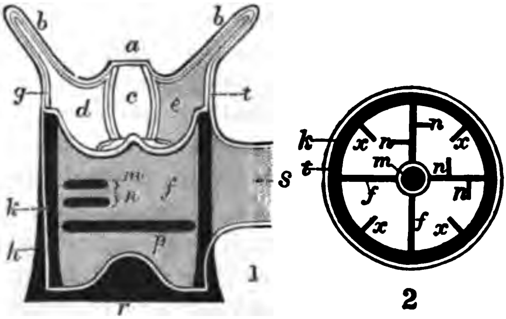


Fig. 22.

1. Vertical Section of Sclerodermic Corallite (after Huxley). *a*, mouth; *b b*, tentacles; *c*, stomach; *d*, inter-mesenteric chamber; *e*, mesentery; *f*, septum; *g*, endoderm; *h*, epitheca; *k*, theca; *m*, placed below columella; *n*, dissepiments; *p*, tabula; *r*, sclerobase; *s*, cœnenchyma; *t*, ectoderm. 2. Transverse Section of the same (the letters refer to the corresponding parts in each figure); *x x x x*, imperfect radii or "pali."

In Fig. 22 diagrammatic sections of the Sclerodermic corallum are depicted. The Sclerodermic corallum is secreted by the "ecderon" or inner of the two layers, into which the "ectoderm" (*t*) is divided, and, according to the nature of the organism, may be simple or compound, consisting, in the latter case, of several

"Corallites," connected by a common substance, or "cœnenchyma" (*s*). The corallum further occupies the lower portions only of the polypes; the upper portion of each polype being more or less free from the coral secretion, and corresponding in every detail to the structure of the typical Actinozoon already described. An outer wall of corallum, surrounding the polype, and termed the "theca" (*k*), is first to be noticed; the "theca" terminating superiorly in a cup-shaped depression, to which the name of "calice" is applied. A central pillar or "columella" (*m*) runs in the vertical axis of the structure, and from the "columella" as a centre to the theca, a variable number of radiating partitions or "septa" (*f*) dividing the intervening space into "loculi" or chambers, is observed. These "septa" correspond in position and relation to the "mesenteries" of the typical Actinozoon, or of the polype under consideration, as seen in the upper part of the figure (*e*), unoccupied by corallum. The septa are further analogous with the "mesenteries," in that they also exhibit variations in size and length, the more perfect being attached to the columella, and corresponding to the "primary" mesenteries; whilst the less perfect "pali" are analogous to the "secondary" or "tertiary" mesenteries. Certain other partitions, dividing the structure *transversely*, also exist. The larger of these, termed "tabulæ" (*p*),—and characteristic principally of extinct corals,—extend completely from side to side, whilst the shorter partitions or "dissepiments" (*n*), springing from the sides of the "septa," also divide the "loculi," but in a less complete manner than the tabulæ. Transversely viewed, we have a wheel-like structure presented for consideration, the rim of the wheel corresponding, so far as the corallum is concerned, to the "theca" (2, *k*), the nave of the wheel to the "columella" (*m*), whilst the perfect spokes (*f f*) represent the complete "septa," the imperfect radii or "pali" (*x x x x*) corresponding to the secondary and imperfect partitions. Springing from the "septa," the transversely-placed "dissepiments" (*n n n n*) are also seen. Lastly, the common coral substance by which the various "corallites" are united, is termed the "cœnenchyma" (1, *s*), this structure corresponding to the "cœnosarc," or common medium by which the polypites of the compound Hydrozoa are united together. Examples of Sclerodermic Corals are found in the *Tubipora musica* or organ-pipe Coral (Fig. 26, *a*); whilst the Red Coral of commerce, and the *Isis* or Mare's Tail Coral, depicted at Fig. 26, *b*, offer examples of the Sclerobasic variety, which usually exists as a more or less solid internal trunk or axis, variously branched or divided, and covered by the soft cœnosarc or common and investing flesh. The Sclerobasic corallum is secreted by the *outer* surfaces of the polypes, the position of the surfaces being, however, reversed, and the true outer surface appearing as an internal one; or, to use the explicit words of Professor Greene, "the Sclerobasic corallum is in fact outside the bases of the polype and their connecting cœnosarc, which, at the same time, receive support from the hard axis which they serve to conceal. Thus the cœnosarc of these Corals appears as a soft fleshy covering, from which the several polypes arise, their somatic cavities freely communicating one with another."

In Fig. 26, *b*, the relation of parts in the *Isis* is well seen, the polypes being borne by the external cœnosarc, the inverted outer surface secreting the central and internal skeleton.

In texture and composition the coral-secretion varies greatly, ranging from a great degree of hardness to a horny and flexible consistence. In the Madrepores and Red Coral the former variety is exemplified. In the *Gorgonidæ*, represented by the Sea-fans, the corallum is corneous or horny; whilst in Isis it is composed of alternate corneous and calcareous joints. The Madrepores (*Madreporidæ*), and the Star and Brain Corals (*Astræidæ*, *Meandrina*), which find a place in every museum, present familiar examples of the Zoantharia Sclerodermata, and at the same time exemplify the best known of the reef-building forms. The geologist ranks the coral-producing polypes among the most important of the organic agencies, which tend to modify and alter the crust of the globe. The South Pacific Ocean, the coasts of Australia, and the adjacent lands, form the chief scenes of the labours of the coral polypes; the geographical distribution of these forms, however, extending over a large area of the southern portion of our globe. A certain temperature, said to be not lower than 66° F., appears to be requisite for the due development of the typical forms, and they are, accordingly, found in greatest profusion in southern latitudes.

Three kinds of coral-reefs are, according to Mr. Darwin's classification, to be distinguished, each variety at the same time representing a stage in the formation of the typical and complete structure. The first form of reef is known as a fringing-reef, and is so named because it skirts or borders the original coast-line of a country. Fringing-reefs are never situate in any great depths of water, the soundings on their seaward aspect showing depths averaging about 25 fathoms.

The barrier-reef is separated from the land by a strip of water, varying greatly in breadth, the depth of this intervening channel being comparatively slight, whilst the soundings on its outer or oceanic side reveal a very great depth of sea.

The third kind of reef is known as an atoll or lagoon reef, and presents a highly characteristic form. The atoll exists as a circular ring or belt of coral-structure, enclosing a sheet of still water, termed a "lagoon," the lagoon usually communicating by a narrow channel with the outer ocean.

The first requisite for the development and life of the coral polypes, as we have seen, is a certain temperature of sea; and a second condition of life is found in the fact that the true reef-building corals cannot exist at a greater depth than from 25 to 30 fathoms. And the solution of the problem thus presented—namely, the erection, in consistency with this latter fact, of coral-reefs rising from unfathomable depths of sea—was a matter which, until the promulgation of Mr. Darwin's theory, received no satisfactory explanation. This theory, now universally accepted, involves the consideration of the phenomena known as the elevation and depression of land, and on the due appreciation of this series of physical changes rests the satisfactory explanation of the erection of coral-reefs. A fringing-reef, accordingly, is one which indicates a stationary condition of the land, the margins of which it fringes. The barrier-reef, in like manner, evinces the active and continuing depression of the land; whilst the atoll, completing the series, indicates the total subsidence of original soil. Thus, by a reference to Fig. 23, the import of these stages will be rendered intelligible. At 1, Fig. 23, we have a section of a fringing-reef, the primitive land being represented

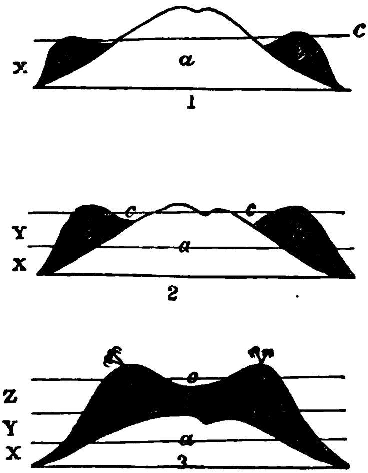


Fig. 23. Formation of Coral-Reefs.

a, Original land; b, Coral structure; c, Sea and sea-level. The capitals, X Y Z, refer to the various and corresponding stages in the process.

at *a*, the coral structure at *b*, and the sea-level at *c*. The coral polypes have thus constructed, at a suitable depth for themselves (25 to 30 fathoms), on the sides of the supposed island (*a*), the fringing-reef (*b b*). But the land, in accordance with the theory, begins gradually to subside, and the polypes, being carried beyond their depth, perish and die; those at the upper portion of the structure still and ever continuing to produce other polypes, and so to build upwards, until we have the barrier-reef formed (2), enclosing a channel of water (*c c*) between itself and the original land, the depth on the ocean or seaward aspect of the barrier-reef being consequently very great. Still the subsidence continues, and depression goes on, until, like a dethroned monarch, the original land has disappeared in the deep. Meanwhile, the operations of the polypes have kept pace with the depression, and new growths have been deposited as the older series died, and were carried downwards, until there rises from the old forgotten land a new and wondrous structure. A section of the atoll (3), therefore, reveals a correspondingly characteristic appearance, the submerged land being now viewed below the sea-level, and on each side (seen in section), but in reality encircling the land, we have the ring of coral-structure (*b*), enclosing the lagoon (*c*) or atoll; the typical form of the atoll being thus due to the peculiar circumstances of its erection. The final stages in the completion of the work consist in the formation of a soil from sea-weeds and decaying vegetation, which may drift upon the reef, and the germination of plants from seeds borne thither by the winds, the luxuriance of vegetation on these reefs being unequalled in any other part of the globe. The theory, as it at present stands, involves therefore two elements; the first a physical one, represented by the phenomena of the elevation and subsidence of land; the second a physiological element, included in the conditions under which the coral-polypes can only exist; these conditions being represented, firstly, by a certain temperature, and secondly, by a limited depth of sea.

Of the time required for the necessary physical changes, and for the consequent growth of the coral-structures, only a feeble idea or approximation can at best be given, since geology possesses but a relative chronology. This much, at all events, is certain, that such physical actions take place by slow and imperceptible degrees,—so gradually, indeed, that our ordinary notions of time are inadequate to fitly express the relations of the action to the period required for its accomplishment. The entire series of phenomena included under the present subject, forms an important link in the chain of evidence to be adduced in favour of the antiquity of our earth, and of the similarity and uniformity of natural action which has existed from the beginning of time.

Sub-order (*c*) *Zoantharia sclerobasica.*—The relations of this group, being but imperfectly determined do not call for special notice. The *Antipathidæ* and *Hyalonemadæ* or "Glass Zoophytes" are the two families included within its limits. The corallum is sclerobasic, and the tentacles are arranged in multiples of six.

Order 2. *Alcyonaria.*—The Alcyonium, or "Dead-man's-finger" polype (Fig. 24), forms the typical representative of this group, the members of which are, with a single and indefinite exception, of compound structure, the polypes being united by a common flesh or "cœnosarc." The tentacles are fringed in a pinnate or feather-like manner, these organs, together with the soft parts, being arranged in multiples of four. A corallum, which in the majority of cases is of the sclerobasic variety, occurs generally throughout the group.

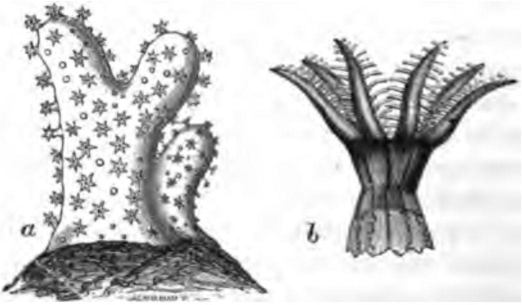


Fig. 24. Morphology of Alcyonaria.
a, Mass of *Alcyonium digitatum*, showing the polypes; *b*, single polype magnified, showing the pinnate tentacles.

(*a*), Family *Alcyonidæ.*—Of this family the *Alcyonium* (Fig. 24) may be taken as the representative. The organism is found attached to shells and other substances, and appears as a soft fleshy mass; its digitate appearance suggesting the familiar names of "Cow's-paps," "Dead-man's-fingers," and the like. When distended with water, the small polypes, each possessing the characteristic circlet of eight pinnate tentacles, are to be distinctly recognised protruding their bodies from the general cœnosarc. At Fig. 24, *b*, an individual polype is represented. A peculiar system of canals, by means of which a constant circulation of water is maintained throughout the entire organism, has been observed.

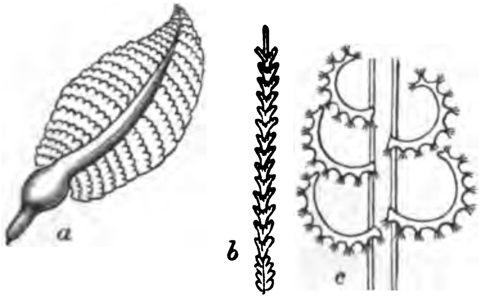


FIG. 25. PENNATULIDÆ.

a, *Pennatula phosphorea*; *b*, *Virgularia mirabilis*; *c*, Portion of the same magnified.

Calcareous spicula scattered throughout the cœnosarc represent the corallum of this family.

(*b*), Family *Pennatulidæ*.—The "Sea-pen" family is typically represented by the organism familiarly known by that name, and scientifically as the *Pennatula* (Fig. 25, *a*). The organism consists of a main stem, bearing lateral branches, the polypes being borne on these lateral pinnæ. The proximal extremity of the stem is destitute of pinnæ, the Pennatula attaching itself by this fleshy part to the sand or mud of the sea-bottom. The corallum is sclerobasic. To the *Pennatulidæ* also belongs the *Virgularia*, or Sea-rod (Fig. 25, *b c*), so named from its slender rod-like appearance. The polypes are borne on lateral processes of small size.

The Pennatulidæ, in common with forms previously noticed, possess the faculty of causing at night a phosphorescent light. From the fact of its possessing this power to a remarkable extent, one species has received the distinctive name of *phosphorea* (Fig. 25, *a*).

(*c*), Family *Tubiporidæ*.—This family includes but a single genus, the well-known *Tubipora musica*, or "Organ-pipe" Coral (Fig. 26, *a*). The Sclerodermic corallum is somewhat modified in the present instance, the "thecæ" being connected by horizontal plates (epithecæ), and septa being absent. Each theca is represented by a simple tube, containing the polype,

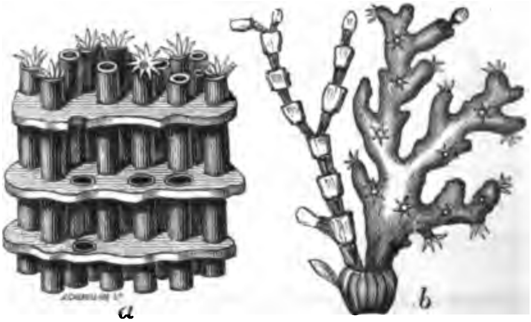


Fig. 26. TUBIPORIDÆ AND GORGONIDÆ.

a, *Tubipora musica*; *b*, *Isis hippuris*, showing part of the central axis (sclerobasis).

which is of a light green colour, and thus presenting a striking contrast to the coral structure, this latter being coloured crimson-red. The polypes possess the power of withdrawing themselves within the tubes when alarmed or irritated.

(*d*), Family *Gorgonidæ*.—The last family of the Alcyonaria includes the Sea-fans (*Gorgonia*), and Red Coral (*Corallium rubrum*); the sclerobasic corallum being in the present instance typically developed. The Gorgonidæ are usually branched in form, and are firmly rooted by the lower or proximal extremity. The corallum may be corneous or horny, as in Gorgonia; horny and calcareous, as in *Isis* (Fig. 26, *b*); or calcareous and of very hard consistency, as in the Red Coral. The Red Coral is much valued on account of its great hardness, which renders it susceptible of receiving a high polish. The investing cœnosarc is of a crimson colour, and through apertures in the flesh the eight fringed tentacles of the polypes are protruded. The Red Coral is confined in its distribution to the Mediterranean Sea, and principally to the eastward coasts of the sea. The coral-fishery is carried on by means of boats, furnished with heavily weighted nets, these latter being dragged across the sea-bottom, and in their passage breaking off the stems of coral, which, being entangled in the nets, are thus secured. As the growth of this coral takes place but slowly, strict laws are in consequence said to be imposed on the coral-fishers, who are thus forbidden to visit the same localities too frequently, and stated periods being enacted for their visitations.

Order 3. *Rugosa.*—The Rugosa are represented solely by extinct coralline forms. The corallum appears to have been sclerodermic, and the parts to have been arranged in multiples of four. The presence of complete transverse partitions, or "tabulæ," also appears to have formed a characteristic feature of Rugose corallites. The order is supposed to occupy an intermediate position between the two preceding divisions.

Order 4. *Ctenophora.*—This order forms the last and highest of the class. The *Ctenophora* are so named from the possession of bands of cilia, or "ctenophores," arranged in comb-like plates. There is no corallum, and thread-cells appear to be very generally present. The animals comprised within this group are free and oceanic in their habits: they are of transparent and gelatinous constitution, and thus present a marked contrast to the preceding groups.

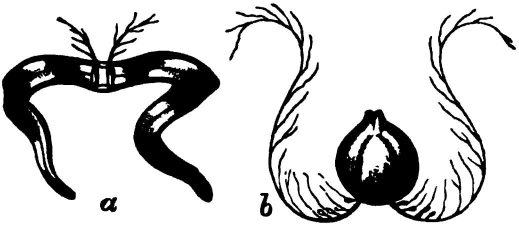


Fig. 27. CTENOPHORA.
a, Cestum Veneris; b, Pleurobrachia pileus.

In many respects the structure of the Ctenophora indicates a marked advance on the ordinary Actinozoic type. In form, a wide diversity is apparent between the members of this group: the *Pleurobrachia* (Fig. 27, *b*), exemplifying the spheric shape; whilst the *Cestum Veneris* (Fig. 27, *a*), or "Venus's girdle," exhibits a band-like appearance.

The former may be taken as a typical example of the group, the structural relations of which have yet to be thoroughly investigated. Externally, Pleurobrachia presents for examination a spherical body, at one pole of which the mouth is situated (Fig. 28, *a*); the opposite pole being termed "apical," in contradistinction to the "oral" extremity of the body. Eight bands or "ctenophores," bearing cilia arranged in comb-like tufts, arise from the neighbourhood of the oral aperture, and terminate near the "apical" pole, the body being thus divided into a number of crescentic spaces. Two long and flexible tentacles (*f f*), fringed with vibratile cilia, and capable of being quickly retracted within special cavities or sacs (*e e*) situated at their origin, stretch away from the sides of the mouth, which opens inferiorly into a stomach (*b*). This organ is furnished, at its lower extremity, with certain cellular bodies, to which a hepatic or liver function has been assigned. The stomach, in turn, terminates in a funnel-shaped cavity, or "infundibulum" (*c*), and from this latter three pairs of canals are observed to proceed. The first

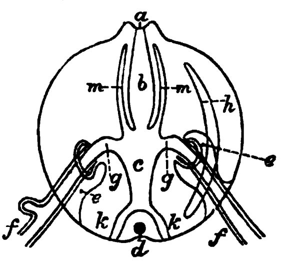


Fig. 28. DIAGRAM OF CTENOPHORE.
a, Mouth; *b*, stomach; *c*, infundibulum; *d*, ctenocyst; *e e*, sacs of tentacle; *ff*, tentacles; *g g*, radial canals; *h*, ctenophoral canal; *k k*, apical canals; *m m*, paragastric canals.

pair, termed the "apical" canals (*k k*), open from the lower portion of the infundibulum, and terminate at the "apical" pole of the body, in the "apical" pores. The second pair, known as "paragastric" canals (*m m*), arise from the upper part of the funnel, and terminate in shut sacs near the oral aperture; whilst the third pair, or "radial" canals (*g g*), proceed toward the margin of the body, and, after dividing into a number of smaller tubes, open into the "ctenophoral" canals (*h*), these latter immediately underlying the ctenophoral bands of the external surface of the body. The office of these canals appears to be that of a vascular or circulatory system, the internal surfaces of the canals being fringed with cilia, which aid in maintaining a due and constant circulation. On careful examination, the entire system, thus described, is found to correspond with the disposition of parts in the typical Actinozoon, the homological relations of the group being thus preserved and demonstrated. Thus, the digestive sac in the Ctenophora corresponds to that of Actinia in position, and relations also, and the ctenophoral canals may be considered homologous with the chambers into which the somatic or body-cavity of Actinia is divided. Situated at the apical pole, a small organ, termed the "ctenocyst" (*d*), is found. This consists of a small cyst or vesicle, in which particles of mineral matter are developed, and from the fact of a nervous ganglion being found in close proximity to the ctenocyst, this latter organ has been considered as representing an auditory organ. In this nervous ganglion the first indication of the specialisation of a nervous system is witnessed.

Pleurobrachia (*Cydippe*), (Fig. 27, *b*) forms a typical example of the order. The *Cestum Veneris* (Fig. 27, *a*) is the only remaining member of the order which merits our special attention. The body is elongated in a lateral direction, to form a band-like structure, the edges of which are abundantly supplied with cilia. It is supposed to possess the power of causing a phosphorescent light, which, in the dark, gives it the appearance of a long waving band of flame.

CLASSIFICATION OF CŒLENTERATA.

CLASS I. HYDROZOA.
- Order (a) *Hydridæ.* Ex. Hydra.
- Order (b) *Corynidæ.* Ex. Cordylophora.
- Order (c) *Sertularidæ.* Ex. Sertularia.
- Order (d) *Calycophoridæ.* Ex. Diphyes.
- Order (e) *Physophoridæ.* Ex. Velella.
- Order (f) *Medusidæ.* Ex. Medusa.
- Order (g) *Lucernaridæ.* Ex. Lucernaria.

CLASS II. ACTINOZOA.
- Order (a) *Zoantharia.*
  - Sub-Order 1. *Z. Malacodermata.* Ex. Actinia.
  - Sub-Order 2. *Z. Sclerodermata.* Ex. Madrepores.

CLASS II. ACTINOZOA—*continued.*

- Sub-Order 3. *Z. Sclerobasica.* Ex. Antipathes.
- Order (b) *Alcyonaria.* Ex. Alcyonium.
- Order (c) *Rugosa.* (Extinct.)
- Order (d) *Ctenophora.* Ex. Cydippe ; Cestum Veneris.

CHAPTER VI.

ECHINOZOA.

General Characters—Classification—Echinodermata.

THE *Echinozoa*, forming the third structural type or plan, were formerly classed with the Cœlenterata, under the common term *Radiata;* and the term *Annuloida* has also been applied to this sub-kingdom, from certain affinities possessed by the Echinozoa to the members of the next and higher type—that of the *Annulosa*. The term Echinozoa is, however, to be preferred to that of Annuloida, inasmuch as the former name expresses a very general characteristic of the group, and also, because the use of the first-mentioned term is less likely to cause any confusion of ideas in distinguishing between the types themselves. The term Echinozoa is derived from the Greek *echinos*, translated a hedgehog, or prickly animal; and in the typical example of the sub-kingdom, the Echinus or Sea-urchin, the application of the term is at once apparent, the shell being covered or set with spines. To the Echinozoal type, however, are referred certain forms, which at first sight would appear to find a more appropriate locality amongst the Annulosa. The class

Scolecida, embracing, among other forms, various parasitic worms,—the most familiar of which are the tapeworms,—is included in the present sub-kingdom, from the exhibition of several unmistakable affinities to the Echinozoal type of structure; and the *Rotifera*, familiarly known as "Wheel-animalcules," the proper place of which has for long formed a matter of discussion, have, in accordance with the latest and most acceptable views, been also included in the present group.

With regard to general characteristics, the Echinozoa possess a distinct alimentary canal, completely differentiated and shut off from the general cavity of the body. In all, a peculiar system, known as the "aquiferous," "ambulacral," or "water-vascular," system exists. A true circulatory or blood-vascular apparatus is present in many instances, whilst a nervous system is very generally found throughout the group.

Classification.—The Echinozoa are divisible into two classes—

Class I.—ECHINODERMATA.
Class II.—SCOLECIDA.

Class I. ECHINODERMATA.—In this division are included the *Echini* or Sea-urchins, the Starfishes (*Asteroidea*), and other typical though less familiar forms. The Echinodermata afford striking examples of the radial symmetry or spherical disposition of parts. Calcareous or limy structures are developed to a greater or less degree in the integument or "perisome," as the outer membranous skin is technically termed. Thus, in Echinus, the calcifying process reaches the acme of its development, a completely-formed shell or "test" being the result; in the integument of the Starfish, on the contrary, in which the deposition of calcareous matter is limited, a modification of the process is well exemplified. In this division, also, the peculiar "ambulacral" system may be most satisfactorily studied, the various structural features of the system being, in the Echinodermata, most highly developed.

Selecting for examination the common Echinus or Sea-urchin, the morphology of the group may be comprehended under the following heads :—

(*a*) Shell or "test, "and appendages.
(*b*) Digestive system.
(*c*) Circulatory system.
(*d*) Nervous system.
(*e*) Ambulacral system.

(*a*) *Shell or "test."*—The spherical shell or test in which the body of the Echinus is enclosed, is composed of calcareous plates, firmly welded together, and arranged in definite sets or series. At the inferior pole of the body the mouth is situated, the anus opening at the opposite and superior pole. The plates of which the test is composed are arranged in ten series, zones or rows, each of these zones being composed in turn of a double row of plates. On the plates of five of these double rows (Fig. 29, *b*; Fig. 30, *e*), small apertures are found, by which exit is given to the "ambulacra" or tube feet; whilst on the plates of the remaining five, and alternating rows (Fig. 29; and 30, *f*), no apertures are observed. The zones bearing ambulacral apertures are, accordingly, known as "ambulacral areas;" whilst the latter zones, composed of imperforate plates, are in contradistinction termed "interambulacral areas." Modifications of this general arrangement are found in the neighbourhood of the mouth, and also at the anal opening. At the superior or anal pole five plates (Fig. 30, *c*) of special structure are found surrounding the anal opening. Each of these five plates is perforated by a single aperture, representing the opening of a generative duct, and to this series the term "genital" plates has been applied. On one of the genital plates is borne a disc-like tubercle, perforated by a number of minute apertures, and known as the "madreporiform" plate (*b*). A series of smaller plates alternates with the "genital" plates, and to these latter the term "ocular" (*d*) is applied. Each "ocular"

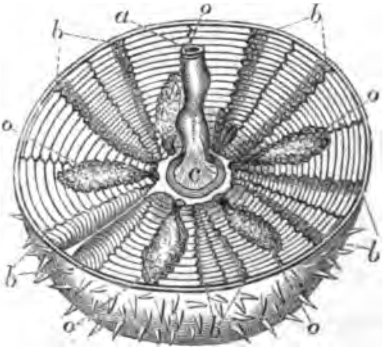


Fig. 29. Upper half of Shell of Echinus Esculentus.

a, Cut extremity of intestine; *b b b b*, Ambulacral areas of shell, showing ambulacral apertures; c, placed above anus; *o o o o o*, Ovaries.

plate is perforated near its outer edge by an aperture, which, during the life of the creature, contains a small "ocellus" or eye, and, from this circumstance, the term "ocular," applied to these plates, is derived. Around the mouth a series of "oral" plates is found, these structures being attached to the strong coriaceous or leathery membrane which surrounds the oral aperture.

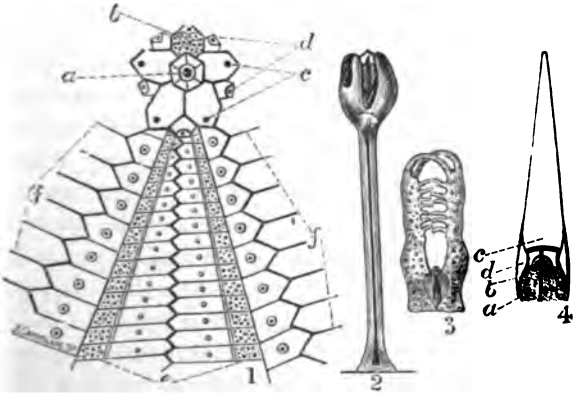


Fig. 30. Echinoidea.

1. Diagram of the arrangement of the plates on the superior aspect of an Echinus-shell. *a*, Anal plate; *b*, madreporiform tubercle, situated on one of the genital plates *c*; *d*, ocular plates; *e*, "ambulacral area," bearing the perforated ambulacral plates; *f*, plates of the adjoining "interambulacral areas." 2. Pedicellaria of *Echinus miliaris* (magnified), (Gosse). 3. Part of the head of the same, showing the skeleton of the "blades." 4. Morphology of a single spine. *a*, Tubercle of the shell; *b*, ligament attaching spine to tubercle; *c*, spine; *d*, muscular capsule investing the joint.

The appendages of the "test" number three different sets: firstly, the spines; secondly, the ambulacra or tubular feet, which may conveniently be included at this stage; and thirdly, a number of small parasitic structures, to which the term "pedicellariæ" has been applied. On more detailed examination of the plates of which the "test" is composed, we find that the plates of both "areas" bear a large number of small tubercles or rounded projections, these, however, being most numerous on the interambulacral tracts. To these tubercles the spines are attached, the articulation partaking of the nature of a ball-and-socket, or universal joint, and free and unimpeded movement of the spines being thus permitted. The attached extremity of the spine (Fig. 30, 4 *c*) exhibits a concavity which articulates with a corresponding and convex eminence situated on the tubercle (*a*). A strong ligament (*b*) passes to attach the spine to the tubercle, whilst a muscular capsule (*d*) encloses the joint; this latter being the chief agent by which the movements of the spine are produced. The spines serve as organs of defence, but they also appear to assist materially the locomotion of the creature. The "ambulacra" (Fig. 31, *p*) consist of a vast number of tubular prolongations or "feet," which protrude through the apertures of the ambulacral areas. The free extremity of each tube is dilated into a disc, which is provided with a sucker, enabling the creature to attach the "feet" to any substance, and thus afford a fixed point on which movements may be made to depend. The relations of the ambulacra will be further considered when treating of the particular system of which they form part. A third set of appendages is also met with in examining the test. These consist of organisms found attached to most Echinodermata, and to which the term "pedicellariæ" is applied. These pedicellariæ (Fig. 30, 2, 3) are of minute size, and each consists essentially of a stalk, furnished at its free extremity with several movable blades (3), which are observed to be constantly in motion, opening and shutting on each other in an incessant manner. These organisms appear to possess an existence separate and distinct from that of the animal upon which they are parasitic, their movements continuing after the creature itself has ceased to live. The function of these peculiar bodies is unknown; by some

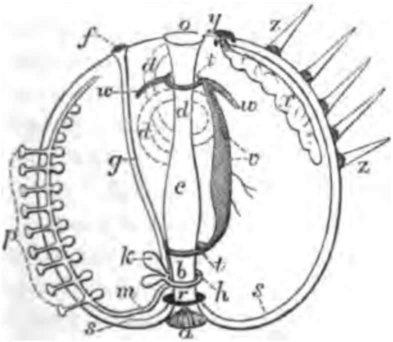


Fig. 31. Diagrammatic Section of Echinus (after Allman).

a, Mouth, with masticatory apparatus ("Lantern of Aristotle"); b, œsophagus; c, stomach; d d d, intestine; f, madreporiform tubercle; g, sand-canal; h, ambulacral ring; k, Polian vesicles; m, an ambulacral tube; o, anus; p, ambulacra, with their basal "contractile vesicles;" r, nervous ring surrounding gullet; s s, two nervous trunks, the right terminating at anal pole in a small ganglion; t t, blood-vascular rings, connected by v, the contractile heart; w w, two arterial trunks, radiating from the anal ring; x, an ovary, opening at the anal pole in a genital plate, y; z z, spines, with their tubercles.

observers, however, they are considered as "spines, modified so as to be mobile and prehensile" (Rolleston).

(*b*) *Digestive System*.—The alimentary canal consists of a mouth, stomach, and intestine, these organs being now specialised; but accessory glands are still wanting. The mouth (Fig. 31, *a*) opens at the inferior pole of the spherical body, and is furnished with a peculiar masticatory apparatus, termed the "Lantern of Aristotle," and which consists of five calcareous jaws, or pointed teeth, united together, and set in action by a complicated muscular arrangement. From this structure a gullet (*b*) leads to a distinct and widened stomach (*c*), from which an intestine (*d d*) is given off. The intestine is attached to the wall of the shell by a delicate and highly vascular membrane, termed the "mesentery," which subserves the absorptive function in conveying to the general cavity of the body the products of digestion. The respiratory function is in all probability also performed by the mesentery, the consideration that its surface is abundantly furnished with cilia, and, indeed, that its general structure appears suited for this office, favouring this opinion. The alimentary canal is encircled in its course by four rings, representing three distinct systems in the economy of the Echinus. Superiorly, we find the two rings belonging to the

(*c*) *Circulatory, Hæmal, or Blood-vascular System*.—The lower ring (*t*) encircles the digestive tract near the gullet, the upper ring (*t*) surrounding the intestinal tube. These two rings are connected by a contractile vessel or heart (*v*), from which (as also from the upper or anal ring) branches (*w w*) radiate to the various parts of the body.

(*d*) *Nervous System.*—The nervous centre in the Echinus exists also in the form of a ring (*r*), which surrounds the gullet at its most superficial portion, the nervous ring being thus the most inferior in position of the systems which encircle the alimentary tube. This ring or cord exhibits several distinct "ganglia," or nerve-masses; and five main nerve trunks (*s s*) proceed from this central point, to be distributed along the ambulacral areas, in company with the branches of the blood-vascular and ambulacral systems.

(*e*) *Ambulacral System.*—The various parts of the ambulacral or water-vascular system may be enumerated under three heads—

1. The *Madreporiform tubercle* and *sand-canal;*
2. The *Ambulacral ring* and *Polian vesicles;* and
3. The *Ambulacral tubes, Contractile vesicles,* and *Ambulacra.*

The (1.) "Madreporiform tubercle" (*f*), as previously noticed, is situated on one of the genital plates which surround the anal pole of the shell. It consists of a perforated disc, and forms the opening of a tube called the "sand-canal" (*g*), which runs downwards from the tubercle, and connects that latter structure with the ambulacral ring (*h*) which surrounds the gullet. The Madreporiform plate is supposed to act as a filter, in serving to admit water to the sand-canal, but at the same time excluding particles of foreign or solid matter.

(2.) The "Ambulacral ring" (*h*) we find surrounding the gullet, and occupying an intermediate position between the centres of the nervous and circulatory systems. Attached to the ring are several pear-shaped vesicles, named, from their discoverer, "Polian vesicles" (*k*); and although their function is still disputed, yet it appears highly probable that they serve as reservoirs or receptacles, to accommodate an increased supply of the fluid used in the ambulacral apparatus. They communicate freely with the ring, from which five radiating tubes—the "ambulacral tubes" (*m*)—proceed; these latter diverging outward, and their course necessarily corresponding to the situation of the ambulacral areas of the shell. (3.) From the "ambulacral tubes," which thus pass along the ambulacral areas, the "ambulacra" (*p*), or tubular feet, are given off; these latter passing through the ambulacral pores of the corresponding plates of the test. At the attached extremity of each tube-foot, and forming a dilatation on the ambulacral tube, a small vesicle, termed a "Contractile vesicle" (Figs. 31, and 32 A, *a*), is found, each tubular foot and its corresponding vesicle being invested with muscular fibres; and, in virtue of the contractile powers with which both feet and vesicles are endowed, fluid can be ejected from the vesicle into the foot, or *vice versa*, as occasion requires. Having thus become acquainted with the morphology of the ambulacral system, we are now prepared to understand the mode in which its function is performed. Water is admitted through the madreporiform tubercle and sand-canal to the ambulacral ring and Polian vesicles. Thence it passes into the radiating ambulacral tubes, filling in turn the contractile foot-vesicles. When, therefore, the creature is desirous of protruding the ambulacra for the purpose of locomotion, it causes the foot-vesicles to contract, and the water being thus forced into the feet, these latter are rendered protrusible, and can be applied to any surface; the terminal suckers enabling them to retain a firm hold. Retraction and inversion of the feet is effected simply by the contraction, in turn, of the muscular walls of the ambulacra; the fluid, being thus forced back into the foot-vesicles, admits of the subsequent retraction of the feet. The feet are capable of being protruded to a much greater length than the spines; and, notwithstanding their apparent awkwardness, these animals effect locomotion in the most perfect manner. In Fig. 32 B, the disposition of the ambulacral ring and accessory structures in the starfish is depicted. The ring itself, bearing the Polian vesicles (*b b*), is seen at *a*, and at *c* the ambulacral tube is seen proceeding in its course, namely, along the inferior surface of the inner aspect of the ray. Three ambulacra or feet are seen in various stages of contraction. In the first of these, *d*, the foot is seen fully protruded, the vesicle being contracted and empty. At *e*, the foot is partially retracted, the fluid contents of the foot partially filling the vesicle; whilst at *f* the foot is represented as being wholly withdrawn, the vesicle being now fully distended with the contained fluid. The muscular investments of the feet (*g h*), from their structure and disposition, are also well calculated to assist in the various movements of the ambulacra.

The generative organs are disposed along the inter-ambulacral areas in the form of five membranous masses (Fig. 29, o, and Fig. 31, x), the efferent ducts opening by the pores borne on the genital plates. The sexes in the Echinodermata are distinct, existing in separate individuals.

Classification.—The class Echinodermata is conveniently divided into four orders—

Order 1. *Echinoidea.* Ex. Echinus.
Order 2. *Asteroidea.* Ex. Asterias.
Order 3. *Crinoidea.* Ex. Comatula.
Order 4. *Holothuroidea.* Ex. Holothuria.

Order 1. *Echinoidea.*—This order is represented by the various families of sea-urchins, many species of which are found around our own coasts. The foreign species attain a large size, and are very varied in form and appearance. The genera *Cidaris* and *Echinus* typically represent the first and most familiar family, that of the *Cidaridæ*—the two remaining divisions, *Clypeastridæ* and *Spatangidæ*, including forms less frequently met with in ordinary observation. In their development the Echinoidea exhibit several remarkable transformations of shape and figure, the embryo—first described as a distinct animal under the name of *Pluteus*—swimming freely as a ciliated body, the perfect form being subsequently developed from but a limited portion of the embryonic body.

Order 2. *Asteroidea.*—Under this head are included the various starfishes. The body consists, in these forms, of a central disc, from which the lobes or arms radiate. The rays vary greatly in number, and also in their relation to the disc. In the common star or cross fish (Fig. 33, *a*) five rays are present; whilst in the

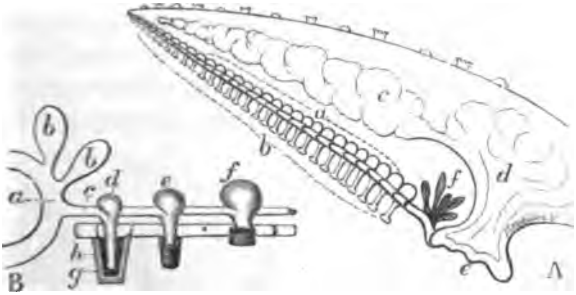


Fig. 32. MORPHOLOGY OF ASTEROIDEA (Rhymer Jones).

A, Ray of starfish dissected, so as to show, *a*, contractile vesicles situated at bases of the ambulacra, *b*; *c*, cæcal prolongation of stomach; *d*, stomach; *e*, mouth; *f*, ovary. B, Ambulacral apparatus of starfish; *a*, ambulacral ring surrounding the mouth; *b b*, Polian vesicles; *c*, ambulacral tube; *d e f*, contractile vesicles and corresponding feet in different stages of contraction; *g*, internal muscular layer of foot, composed of longitudinal fibres; *h*, external layer, composed of circular fibres.

Solasteridæ, or sun-stars, the number ranges from thirteen to sixteen. In their morphological relations with the body or disc, also, the rays exhibit important differences. Thus, in the true starfishes, the arms are immediate and true prolongations of the disc itself, and contain a due proportion of the viscera (Fig. 32, A); whilst in the *Ophiuroidea* or brittle-stars (Fig. 33, *b*), as exemplifying the second type, the arms are mere appendages of the disc, to which the viscera are confined.

In this latter case the arms principally subserve the locomotive faculty. If we conceive an Echinus to be divided along the ambulacral areas, and the resulting ray-shaped divisions to be spread out, whilst a membranous disc would unite and connect the rays at their bases, we should have constructed a form resembling the starfish, the morphological relation of which to the Echinus may thus be roughly expressed. The integument is of a coriaceous or leathery consistence; calcareous particles, representing modified tubercles and spines, being abundantly deposited throughout its substance. An internal arrangement of calcareous plates forms an endoskeleton, serving for the due support of the other and softer tissues. The mouth, which in the present instance is destitute of a masticatory apparatus, is situated on the centre of the inferior surface of the disc, and from the mouth a short gullet leads into a capacious stomach, which, in the true starfishes, sends blind or

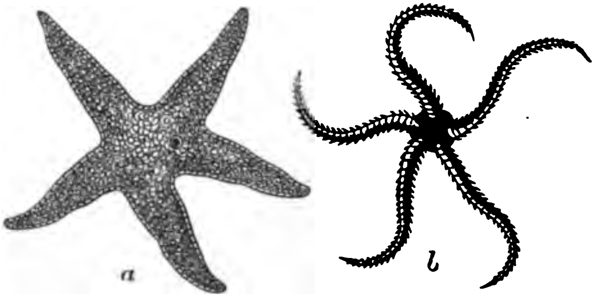


Fig. 33. ASTEROIDEA.
a, Uraster rubens; b, Ophiura texturata.

cæcal prolongations of its substance into each ray (Fig. 32, A). An anal aperture is not generally present. The ambulacral ring surrounds the mouth, the ambulacral tubes proceeding along the inferior surface of the inner aspect of each ray (Fig. 32, A, *a b*). The feet vary considerably in number, two or four rows being present in each ray. The madreporiform tubercles also vary in number, two or three being usually found. The nervous system, as before, surrounds the oral aperture, branches radiating from this central point to the rays. The Asteroidea are abundantly represented on all our coasts: the common starfish (*Uraster rubens*) (Fig. 33, *a*), and the sun-stars (*Solaster pappoea*), being familiar to every sea-side visitor.

The *Ophiuroidea* or "Brittle-stars," sometimes classified as a distinct order, differ from the true starfishes in that the arms are mere appendages to, and not true continuations of, the body, the viscera being confined to the disc itself, which is covered by calcareous plates, as also are the long and flexible arms. The ambulacral tube, as before, is disposed along the floor of each ray; the aquiferous system, in the present instance, is not so perfectly developed as in the true starfishes. The *Ophiura* or sand-star (Fig. 33, *b*), and the *Ophiocoma* or brittle-star, represent the group, the latter form deriving its name from the peculiar habit of breaking itself in pieces when captured. In all the *Asteroidea* the power of reproducing lost or injured members is possessed to a great degree.

Order 3. *Crinoidea.*—The consideration of this order is extremely interesting from a palæontological point of view, the forms included within this limited group serving to connect existing Echinozoa with certain extinct and fossil forms.

The parts of a typical Crinoid may be very shortly enumerated as consisting of a cup-shaped body, or "calyx" (Fig. 35, B, *e*), giving attachment superiorly to grooved arms (*c*), and giving origin inferiorly to a jointed stem or pedicle (*s*), by the roots (*r*) of which the Crinoid attaches itself to the sea-bottom. The calyx is composed of definite series of plates (*b d k*), the mouth (*m*), and in many cases the anal aperture also (*a*), opening in the central aspect of the cup. Jointed processes (*p f*), attached to the arms and stem, are also represented in the figure.

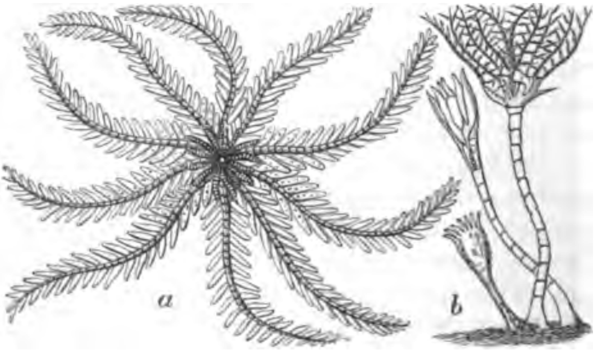


Fig. 34. CRINOIDEA.
a, *Comatula rosacea* (after Forbes); *a*, in its free and adult state; *b*, in its young and attached condition.

The *Comatula rosacea* or feather-star (Fig. 34, *a*), is the sole British representative of the order, which is defined as including Echinodermata, "in which the body is fixed, during the whole or a portion of the existence of the animal, to the sea-bottom, by means of a longer or shorter jointed and flexible stalk." The body, in *Comatula*, consists of a central calcareous disc, from which five radiating arms are given off. These arms bifurcate immediately above their origin, each ray dividing into two branches, and the creature thus possessing ten elongated slender rays. Each of the divisions is furnished with lateral and jointed appendages, to which the name of "pinnæ" has been given; the arms thus possess a pinnated or feather-like appearance, and from this cir-

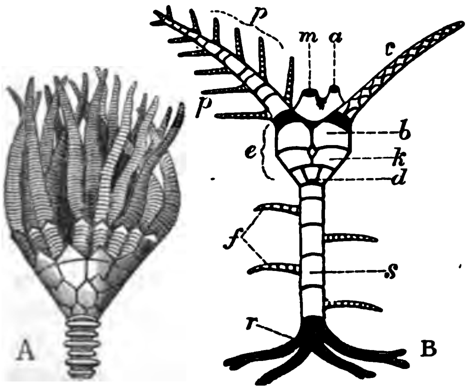


Fig. 35. Crinoidea.

A, *Woodocrinus macrodactylus*, a fossil *Crinoid* from the mountain Limestone. B, Diagram of *Crinoid*. *a*, anus; *b*, brachial or arm plates; *c*, arm; *d*, basal plates; *e*, calyx; *f*, ramules; *k*, intermediate plates; *m*, mouth; *p*, pinnules; *r*, roots; *s*, stem.

cumstance the familiar name of "feather-star" has been derived.

In the young state the Comatula is stalked (Fig. 34, *b*), being supported on a calcareous jointed stem, which is surmounted by the cup-shaped body, to which the ten arms are attached. When the fitting period has arrived, the Comatula breaks away from the stalk, and exists during the remaining period of its life in a free and unattached condition. The young and stalked state of Comatula was formerly described as an anomalous and distinct form, under the name of *Pentacrinus Europæus*, and the several known foreign stalked forms may be supposed, in like manner, to be merely the embryonic condition of other and free Crinoids.

A perfect digestive system, modelled on the Echinozoal type, exists in Comatula; a distinct anus, in addition, being present. The ambulacral system is also developed, but does not subserve the locomotive function to any great degree.

The majority of fossil Crinoidea, on the contrary, were permanently stalked and rooted, the most familiar species being popularly known as *Encrinites* or lily-stars (Fig. 35, A).

It is, however, interesting and important to observe that recent deep-sea dredging explorations, conducted under the direction of Professor Wyville Thomson, Dr. Carpenter, and others, have brought to light certain Crinoidean forms, referable to genera, which, until recently, were thought to be unrepresented by living species. Under the heads *Cystoidea* and *Blastoidea*, several extinct forms, referable to the Crinoidean type of structure, are included, the principal difference between these and true Crinoids consisting in the non-development, in these groups, of arms.

Order 4. *Holothuroidea.*—This order includes the Sea-cucumbers, and Trepangs (*Holothuriæ*), which, from their higher structure, constitute the most advanced division of the class. The Holothuroidea differ widely in form from the preceding groups, the body being more or less elongated (Fig. 36), and of soft or leathery consistence. The deposition of calcareous matter in the integument is limited to the development of a few spicules of this material. The ambulacra are generally short and scattered over the surface of the body, or they may be absent altogether. Locomotion is accordingly affected by the ambulacra when present, or by the general contraction of the body when these organs are absent, the muscular system in the Holothuroidea reaching a high degree of development. The mouth, encircled by a crown of feathery tentacles, is

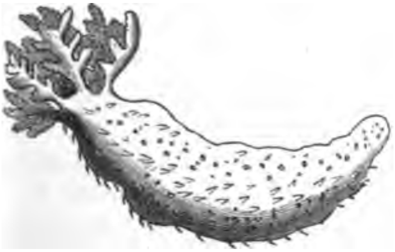


Fig. 36. Holothuroidea. *Cucumaria communis* (Forbes).

situated anteriorly, and leads into a stomach, from which a convoluted intestine, terminating in a dilated chamber or "cloaca," is given off. Two tubes open inwards from this "cloaca," and ramify in the interior of the body. These organs convey water within the system, and collectively constitute a respiratory or breathing apparatus. The disposition of the nervous and circulatory systems presents no features worthy of special remark.

The Holothuroidea attain their greatest size and development in tropical seas; but a few smaller species are found inhabiting deep water around our own shores.

CHAPTER VII.

ECHINOZOA—(*Continued*).

CLASS II. SCOLECIDA.

General Characters—Classification—Platyelmia—Nematelmia—Rotifera.

IN this group are comprised many forms which, until recently, were classed with the *Vermes* or Worms, in the old sub-kingdom *Articulata*, or jointed animals. And although the external appearance of certain typical members of this group might seem to justify their being placed among the Annulosa, yet a more careful and detailed examination of these forms reveals a structure differing so widely from that of the true worms, that of necessity the Scolecida are referred to the lower and Echinozoal type of structure. The term *Entozoa*, or internal parasites, is sometimes applied generally to this class, in allusion to the habits of certain forms included in this group. Yet this term is limited in its signification; and, accordingly, it is seldom or never used in a strictly zoological sense. The *Rotifera*, or "wheel-animalcules," forming the third order of the class, were formerly classified as a division of the lower Annulosa; but their affinities, as regarded by Huxley, seem to warrant their removal to the present sub-kingdom. So far as general characters are concerned, the Scolecida do not, in the main, present very definite affinities to the Echinozoal type. A water-vascular system, corresponding to the ambulacral system of other Echinozoa, is very generally to be distinguished. No true circulatory apparatus is present, and the nervous system is of an inferior type of organisation.

The class *Scolecida* is divided into three orders:—

Order 1. *Platyelmia*, or "flat-worms." Ex. *Tænia*.
Order 2. *Nematelmia*, or "round-worms." Ex. *Ascaris*.
Order 3. *Rotifera*, or "wheel-animalcules." Ex. *Hydatina*.

Order 1. *Platyelmia.*—This order includes a number of jointed or worm-like organisms, of flattened shape or figure. The common Tape-worm (*Tænia solium*, Fig. 37) may be regarded as a typical representative of this group, which, from a medical as well as scientific point of view, is of great interest. Three sub-orders are included in this group, the first of which—that of the *Tæniada*—presents the more special of the characteristics of this curious division.

(*a*) Sub-order *Tæniada.*—The *Tæniada* or Tape-worms, of which the *Tænia solium* is the most familiar example, inhabit, in their mature state, the alimentary canal of warm-blooded vertebrates. The species selected for examination inhabits the intestinal tube of man.

Externally it presents an elongated flattened ribbon-like form, divided throughout its length into segments of oblong shape (Fig. 37, *c*), except at the anterior portion of the organism, where a rounded head (Fig. 37, *b*), supported on a series of constricted segments, forming the neck, is found. The segments of the neck are small and closely set, but the succeeding joints gradually increase in size, those of the posterior extremity forming comparatively large oblong segments, each of which is loosely articulated to the neighbouring joints. The

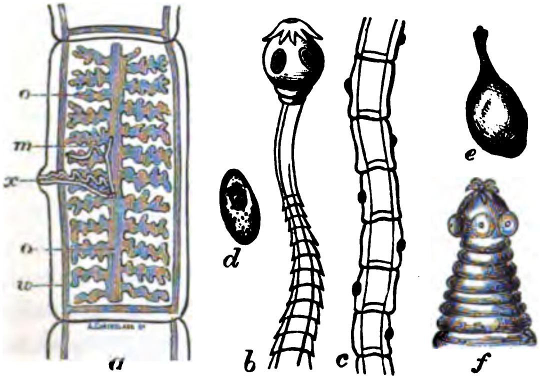


Fig. 37. Morphology and Development of Tæniada.

a, Single segment (proglottis) of *Tænia solium*, magnified and enlarged, to show the branched ovary (*o o*), the generative pore (*x*), the male generative organs (*m*), and the water-vascular system (*w*); *b*, Head and neck segments of *Tænia solium* enlarged, showing the hooklets and suckers; *c*, Portion of Tape-worm (natural size), showing the alternating generative pores. *d*, Free ovum of *Tænia*, with the contained embryo (proscolex); *e*, *Cysticercus cellulosæ*, "Scolex," or encysted condition of *Tænia*; *f*, Magnified head of same, showing hooklets, suckers, and constricted segments forming the neck.

head (*b*), which consists of a small rounded body, is provided with a series of hooks and suckers, by means of which the animal adheres firmly to the mucous or lining membrane of the intestine. The segments are produced from the anterior extremity by a process of continuous gemmation or budding. Each fresh segment, as produced, occupies a position between the head and the segments previously formed; the older and most mature joints being thus situated at the posterior extremity of the body, or are most distant from the head. The head thus constitutes the true animal, the various segments being regarded as sexual zoöids or individuals produced by the asexual "nurse," formed by the head-segments. The mature and ordinary segments or "proglottides" (*a*) are devoted solely to the reproduction of the animal, and contain each a complete generative apparatus, capable of producing fertilised ova, male and female elements being found in each segment. Although organically connected to each other, and by each other to the head segment, the last and most mature segments are continually being detached, and are excreted from the animal in whose interior the Tænia resides; but fresh and new segments are, as we have seen, being continually formed by the anterior extremity, and these, in turn, gradually take the place of the segments which have fallen away.

No trace of a digestive system is seen, the animal living by the imbibition and absorption, through the membranous walls of its body, of the nutritive juices of its host. The water-vascular system (*w*) is represented by a vessel running along each side of the body, communication between the vessels taking place by means of a transverse branch at the articulation of each segment with the neighbouring joint. The nervous system consists of two small anterior ganglia, from which filaments, proceeding to the posterior parts of the organism, are derived.

The generative organs, therefore, occupy the greater part of each joint. The ovary, forming by far the greater bulk of the contained organs, consists of a main trunk or stem, from which lateral branches are given off (*o o*). The male organ exists as a small convoluted tube (*m*), terminating in the posterior part of the segment in a minute vesicle. The efferent ducts of the generative organs open by a small pore (the "generative pore") (*x*), situated on a minute papilla or eminence, placed, in *Tænia solium*, in the centre of the lateral margin of the segment. The position of the generative pore, varying throughout the group, has been used as a means of classifying the various members of the division. The Tænia varies in length as the organism has existed for a longer or shorter period; in many instances, specimens have measured many yards in length; at all times, however, the segments are produced with great rapidity, new and fresh growths continually taking place as the creature continues to exist in a favourable situation.

Each segment being thus capable of producing an immense number of fertilised ova, and the number of segments being also great, it follows that a mature

Tænia is the receptacle of an almost incalculable progeny. But the history of the reproductive process, and the consideration of the various stages through which the ovum and embryo have to pass before the mature and adult form is attained, indicate a merciful provision of nature in thus limiting their growth, and preventing the otherwise rapid increase of these animals. Were it not for the many chances of destruction which involve, and undoubtedly exterminate, the greater part of the ova, during the lengthened and extended cycle of development through which the eggs have to pass, there would be no limit to the propagation of the Tæniada to a dangerous degree.

The stages in the life-circle of a Tænia may be conveniently classed under six heads, corresponding to six distinct periods in the process of development. Beginning with the mature and sexually-perfect segments, or "proglottides," we find that these are being continually discharged from the alimentary canal of the animal in whose interior the Tænia resides. The contained and already fertilised ova (Fig. 37, *d*) of the "proglottis" are liberated by the subsequent destruction and decay of the segment; and, for the further development of these ova, it is necessary that they should enter the alimentary canal of some warm-blooded vertebrate. Having gained admittance to the digestive system of such an animal, the external envelope of the ovum is dissolved, and the minute contained embryo is set free. Its rounded form is now observed to be armed at one point by six siliceous or flinty hooks, by means of which it bores its way through the tissues of its host, until it reaches some organ, such as the liver, which forms a very noted resting-place for these creatures. Or it may take up its abode in the muscular tissues of the animal; but at any rate, and wherever its resting-place is found, the "proscolex"—as the little hooked travelling embryo is called—there develops around itself a cyst, or bladder-like structure, containing fluid, and constituting what is known as the "scolex," or "resting-larva" (Fig. 37, *e f*) of the Tænia. Forms of this description, long known by the name of "Cystic worms," are now ascertained to be merely representatives of one of the transitionary stages in the development of Tænia. Within the cyst or bladder of the "scolex," the head and neck of the future worm are developed, in the form of a small process growing from one of the walls of the cyst. The process of development cannot proceed further until the "scolex" be liberated from the animal in whose tissues it thus lies buried. If, however, the flesh of an animal containing "scolices," be swallowed by some other warm-blooded vertebrate, the further and final stages in the process of development will continue, and be completed. Having thus gained access to the alimentary canal of this second host, the bladder-like cyst is next dissolved by the action of the digestive juices, and the scolex-embryo, now set free, attaches itself to the mucous membrane of the intestine by the already-formed hooks and suckers. The organism next begins to bud, and to develop posterior segments, until at length the mature Tænia or "strobila," with its lengthened train of joints or "proglottides," is produced; each joint being sexually mature, and capable of producing ova, which, in the course of their development, will repeat the wondrous cycle through which we have traced their predecessors and progenitors. The six stages may therefore be thus enumerated—

(1.) The "ovum," or egg (Fig. 37, *d*), set free by the decomposition and decay of the "proglottis," or sexually-mature segment, and containing

(2.) The embryo, or "proscolex," with its six-hooked apparatus for boring through the tissues of the first host, to the place where it becomes

(3.) The "scolex," or "resting-larva" (Fig. 37, *e f*), with its bladder or cyst, containing the head-segments of the future Tænia.

(4.) The immature Tænia, liberated from the cyst of the "scolex," after being introduced into the alimentary canal of its second host.

(5.) The "strobila," or adult and mature Tænia, the result of the further development of the fourth stage; this latter (5) form, producing

(6.) The "proglottides," or sexually-mature segments, with their contained and fertilised ova.

In the case of the *Tænia solium* of man, the life-history of the future organisms has been ascertained with considerable exactitude. The ova liberated from the "proglottides" may be swallowed by the sheep or pig, in which the "proscolex" burrows its way through the tissues of either animal, to become the "scolex." In the pig the development of the cystic "scolices" causes the disease peculiar to that animal, and known as "measles." No further change can take place in the "scolex," unless the pork so affected be eaten by man, in which event the "scolex," becoming liberated from the cyst, attaches itself to the intestinal mucous membrane, and developes into the "strobila," or mature Tænia.

The cystic forms or "Scolices" of one animal become thus developed into the Tænia of another animal. The *Cysticercus fasciolaris*, or cystic worm of the mouse, is in this way developed into the *Tænia crassicollis* of the cat; and, in like manner, the *Cysticercus pisiformis* of the rabbit is the immature *Tænia serrata* of the dog and fox.

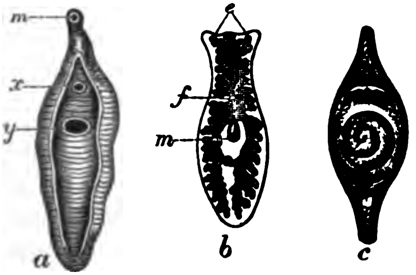


Fig. 88. TREMATODA, TURBELLARIA, AND NEMATODA.

a, *Distoma hepaticum* (enlarged); *m*, anterior sucker; *x*, generative pore; *y*, posterior sucker; *b*, *Planaria lactea*, showing the branched digestive system; *e*, eyes; *f*, digestive canal; *m*, mouth and proboscis; *c*, *Trichina spiralis* in its encysted condition.

(*b*) Sub-order *Trematoda*.—The Trematode worms are typically represented by the *Distoma* or "Flukes," and of these the "Distoma hepaticum" (Fig. 38, *a*), or

"Liver-fluke," is the most familiar species. As its specific name implies, the Distoma inhabits the liver of the sheep, producing the disease known in that animal as the "rot." They are small organisms of a rounded shape, and of a more or less flattened figure, the anterior disc, by which the Distoma attaches itself to the tissues it inhabits, being perforated by the aperture of the mouth, which opens into a curiously-branched alimentary system, consisting of two main branches, from which lateral and blind or imperforate divisions are given off. A water-vascular system is present, and a nervous system of rudimentary construction also exists. The development of Distoma also exhibits a definite cycle, although the changes or stages of its life-history are by no means so frequent or numerous as those of Tænia. The Distoma being voided by the sheep, the contained ova escape, and those which find their way into water undergo a further development. The ciliated embryos, thus liberated from the ova, next take up their abode within the body of some mollusc, the body of the common water-snail being most frequently selected for a habitation. Within the body of the snail the embryo produces a cyst, in the interior of which small bodies, furnished with lash-like tails, and called "Cercariæ," are produced. These Cercariæ next escape into the surrounding water, and, on being swallowed by the sheep, penetrate to the liver, there to become developed into adult Distoma.

(*c*) Sub-order *Turbellaria.*—The *Turbellaria* are distinguished from the members of the preceding groups in being non-parasitic in their habits, and in the general possession of vibratile cilia. Two distinct types of Turbellarians are met with. The *Planarida* (Fig. 38, *b*) are animals of small size and flattened forms, inhabiting both fresh and salt water; whilst the *Nemertida*, on the contrary, are of elongated worm-like shape. The *Nemertes*, or "ribbon-worm," is frequently met with in dredging operations, as an elongated flattened worm, in many instances of very considerable length. The *Planarida* possess a digestive system, which, however, is unprovided with an anal aperture. In the *Nemertida* a distinct anus is present.

Order 2. *Nematelmia*, round-worms. — The forms included in this group are, as the name implies, round or cylindrical in form. No distinct segmentation of the body is discernible. The representative forms are the *Ascaris* or common "round-worm;" the *Echinorhynchus* or "thorn-headed" worm; and the *Gordius* or "hair-worm." The *Ascaris lumbricoides*, representing the (*a*) *Nematoda*, inhabits the human intestinal canal, in which situation the *Oxyuris* or small thread-worm is also found. A distinct mouth, alimentary canal, and a system probably homologous with the water-vascular system of Tæniada, complete the essential structural details of the group. The guinea-worm (*Filaria medinensis*), inhabiting tropical climates, infests the cellular tissue of man, particularly that of the lower limbs. The embryonic worm, which, when mature, attains a length of several feet, burrows its way under the cellular tissue, from which it has to be carefully extracted by coiling its length round some object, an operation which the negroes are said to perform with much skill and dexterity.

The *Trichina spiralis* (Fig. 38, *c*) is a form referable to this group, and which has of late years attracted especial notice. It is generally found infesting the muscular tissue of the pig, large numbers of these worms being found in a single muscle, each enclosed in a little cyst, in which it lies coiled up. In this condition it is sexually immature and incapable of reproducing its species; but when the pork so infected is eaten by man, the active stage of development is at once induced. The Trichinæ in the human alimentary canal become sexually perfect, and the production of young in large numbers takes place with amazing rapidity. The young Trichinæ thus produced bore their way through the tissues from the alimentary canal to the muscles, in which they develop cysts, and in this state they remain quiescent and incapable of effecting further change. The irritation and consequent exhaustion produced by the migration of the young Trichinæ from the digestive to the muscular system, being frequently productive in the human subject of fatal results.

The *Gordius aquaticus* represents the (*b*) *Gordiacea* or "hair-worms," which are so named from their attenuated hair-like appearance. These worms inhabit the bodies of various insects. The (*c*) *Acanthocephala* or "thorn-headed" worms are represented by the *Echinorhynchus*, which inhabits the digestive tract of various vertebrata, birds and fishes being the forms more especially subjected to its visitations. The proboscis is provided with hooks, by means of which the worm adheres to the mucous membrane of the intestine.

Order 3. *Rotifera.*—The Rotifera are microscopic animalcules, inhabiting fresh water pools, and distinguished by the possession of "an anterior ciliated disc," capable of protrusion and retraction, the vibratory movements of the cilia with which the disc is furnished giving the observer to suppose that he sees a rotating wheel, and from this circumstance the familiar name of "Wheel-animalcules" has been derived. The function of this ciliated disc is of a twofold nature, its action subserving the locomotive function, and also creating currents in the surrounding water, by which food-particles are drawn towards the oral aperture. The Rotifera may exist either as free swimming organisms, or as fixed

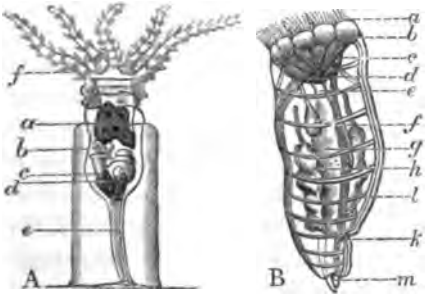


Fig. 39. Morphology of Rotifera.

A, *Stephanoceros Eichornii*: *a*, pharynx; *b*, gizzard; *c*, stomach; *d*, ovary; *e*, foot, or attached extremity; *f*, ciliated tentacles. B, Anatomy of *Hydatina senta* (female): *a*, cilia; *b*, ciliary discs; *c*, muscles of jaws: *d*, ganglia; *e*, gullet; *f*, salivary gland; *g*, stomach; *h*, ovary; *k*, anus; *l*, vascular system; *m*, terminal forceps.

forms; the *Hydatina senta* (Fig. 39, B), exemplifying the former variety, whilst the *Stephanoceros*, or "Crown animalcule" (Fig. 39, A), represents the latter forms. The males are of small size as compared with the female Rotifera, in which the typical structure of the group must needs be examined.

The *Hydatina*, one of the best known forms, may well exemplify the structural features of the order. The body in Hydatina is somewhat of an ovate form, and exhibits distinct annular or ring-like markings. The anterior extremity bears the ciliated rotary discs (Fig. 39, B, *a b*), whilst the posterior extremity is prolonged to form an abortive tail, which in some instances is furnished with rudimentary prehensile organs (forceps, *m*), or with a suctorial disc. The mouth opens at the inferior portion of the rotating disc, and leads into a dilated pharynx, furnished, in the case of the females only, with a complicated masticatory apparatus (*c*). The pharynx is continued inferiorly into an œsophagus (*e*) and stomach (*g*), from which an intestine is given off, to terminate in a "cloaca" (*k*), which also receives the efferent ducts of the generative organs, and from which the water-vascular system (*l*) takes its origin. This latter system is represented by a "contractile vesicle" opening from the "cloaca," and from this vesicle two tubes proceed, which pass to the anterior extremity of the body, to terminate in cæcal or blind prolongations. The function of this system, as in the other forms, is probably respiratory; but it is believed to act as an excretory apparatus also. The nervous system consists of a ganglionic mass (*d*), situated anteriorly, and near the gullet. A minute pigment-cell (ocellus), to which the function of sight has been allocated, rests upon and derives its nervous supply from the ganglion. The generative organs (*h*) occupy, in both sexes, no inconsiderable portion of the body-cavity; the male Rotifer being essentially "a locomotive testis." The oviducts terminate, as previously remarked, in the "cloaca." The muscular system of the Rotifera exhibits a high degree of specialisation, the movements of the disc, jaws, viscera, and body generally, depending on the muscular investments of the various organs and parts.

The Rotifera possess a remarkable power of revivification, after existing in a seemingly lifeless condition for a longer or shorter period. They may be dried up by the heat of the summer sun, from the pools they inhabit, and be blown about by the wind as microscopic specks, in the form of dust, continuing in this mummified condition for months, or even years; yet, upon the addition of moisture, they again spring into activity, and resume the functions of life with renewed vigour.

CLASSIFICATION OF ECHINOZOA.

CLASS I. ECHINODERMATA.
  Order (a). *Echinoidea.* Ex. Echinus.
  Order (b). *Asteroidea.* Ex. Asterias.
  Order (c). *Crinoidea.* Ex. Comatula.
  Order (d). *Holothuroidea.* Ex. Holothuria.

CLASS II. SCOLECIDA.

Order (a). *Platyelmia.* Ex. Tænia.
Order (b). *Nematelmia.* Ex. Ascaris.
Order (c). *Rotifera.* Ex. Hydatina.

CHAPTER VIII.

ANNULOSA.

General Characters of Annulosa—Classification—Gephyrea—Annelida.

The great bulk of Annulose animals were formerly included under the old division *Articulata*, or "jointed" animals; and an inspection of the external appearance of a typical example of this sub-kingdom—such as a Worm or Centipede—at once justifies us in describing their bodies as composed of "somites," zones, or segments, arranged "along a longitudinal axis." This appearance is described by zoologists under the term "vegetative repetition of parts," the essential of which definition consists in the fact of the segments being prototypes of each other; they are, in other words, constructed upon the same type or plan. Such a structure also exemplifies the regular and definite succession of parts, to which the term "serial homology" is applied.

A longitudinal section of a typical Annulose animal—such as a Worm (Fig. 40, 1)—shows us a distinct digestive system (*b*), completely differentiated and shut off from the general (or somatic) cavity of the body, and running through the centre of the body in a more or less straight and defined course. Superiorly to the alimentary canal, and situated on the "dorsal" or back surface of the animal, we find the "hæmal" or blood-vascular system (*a*), whilst the nervous system (*c*) occupies the inferior or "ventral" aspect of the body. The nervous system of the Annulosa presents an exceedingly characteristic structure, consisting, in the typical forms, of a double chain of ganglia or nerve-centres, these latter being intimately connected together by cords of nervous matter. Diagrammatically represented, as in Fig. 40, 2, two ganglia are seen to exist in the floor of each segment of the body; and

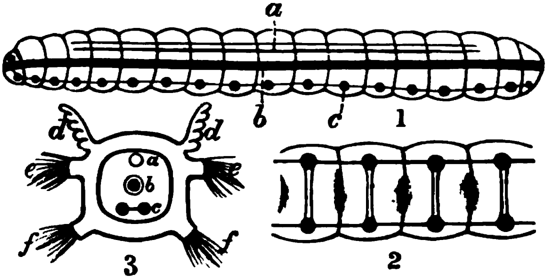


Fig. 40. MORPHOLOGY OF ANNULOSA.

1. Diagram of a typical annulose animal: *a*, blood-vascular system; *b*, digestive system; *c*, nervous system. 2. Diagram of nervous system of typical annulose animal viewed from above, and showing the double ventral gangliated chain. 3. Transverse section of a typical annelide: *a*, blood-vascular system; *b*, digestive system; *c*, nervous system; *d*, branchiæ, or gills, borne on the dorsal arc; *e*, "notopodium," or "dorsal oar," bearing a jointed filament (cirrhus) and bristles (setæ); *f*, "neuropodium," or "ventral oar," bearing similar appendages.

from these ganglia as centres, nerves arise to supply the adjacent parts and organs. In the higher forms the tendency to specialisation of the nervous system is witnessed in the coalescence and union of the separate ganglia, a single and compound nervous cord being thus formed. The regularity of this arrangement of the nervous system in the typical Annulose forms, it may be lastly noticed, has been included by Professor Owen as a special feature in his definition of the group, his term *Homogangliata* being used as synonymous with Annulosa.

Respiration may be performed in various ways—by external or internal gills, as in the Sea-worms and Crustaceans; by air-tubes and pulmonary or lung-sacs, as in Insects and Spiders; or by the general surface of the body, as in certain Worms and allied forms.

The Annulosa are typically represented by Worms, Centipedes, Insects, Spiders, Crabs, etc.

Classification.—The Annulosa are primarily divided into two great sections, characterised by the presence or absence of articulated or jointed limbs:—

Section A. The *Anarthropoda*, or Lower Annulosa, are represented by the various orders of worms. In these forms true jointed limbs are absent, and locomotion is effected by muscular contraction of the body, aided by lateral bristles and appendages.

Section B. The *Arthropoda*, or Higher Annulosa, possess jointed limbs, articulated to the body. This section includes the Centipedes, Insects, Spiders, and Crustacea.

SECTION A. ANARTHROPODA.

Under this section two classes are included—

Class I. GEPHYREA. Ex. Spoon-worms (*Sipunculus*).

Class II. ANNELIDA. Ex. Earthworm (*Lumbricus*).

Class I. GEPHYREA.—In this class are included the various species of Spoon-worms (*Sipunculoidea*)—small worm-like forms, which inhabit the sand of our coasts, or seek protection in the cast-off shells of certain mollusca. They exhibit the essential annulose characteristics, the body being segmented, and the nervous system consisting of the typical ventral gangliated cord. Lateral appendages are wanting, as also are eyes and other organs of sense. A proboscis, bearing the mouth, surrounded by tentacles, is situated anteriorly, the posterior part of the body being comparatively thick and muscular. In Fig. 41, two of the most familiar forms included in this group are depicted.

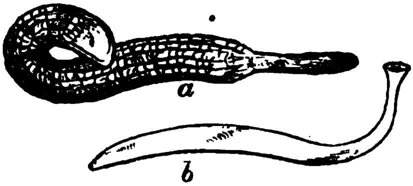


Fig. 41. GEPHYREA (Gosse).
a, *Syrinx nudus*; *b*, *Sipunculus punctatissimus*.

Class II. ANNELIDA.—This class is found to be as extensive as the preceding was limited. It includes the various kinds of Worms. The body in general is distinctly segmented, each zone or segment being furnished with locomotive appendages, the degree of perfection, however, to which these organs may attain, varying considerably throughout the group. A detached segment of the body of a typical Annelid consists of two halves or arcs, named, from their position, the "dorsal" and "ventral" arcs (Fig. 40, 3). From the sides of each arc certain processes, termed "parapodia" or "foot-tubercles" (*e f*), are seen to arise, and of these, four exist to each segment, two being borne by each arc of the segment. The tubercles borne on the dorsal arc are termed, from their position, "notopodia" (*e e*) ; those of the ventral half, from their proximity to the nervous system, being known as "neuropodia" (*f f*). The terms "dorsal oar" and "ventral oar" are sometimes used synonymously with the above names. Each "oar" or "parapodium" bears two distinct kinds of appendages (Fig. 40, 3): firstly, bristles or "setæ," which form the bulk of the organ; and, secondly, a soft tentacular filament, to which the name of "cirrhus" is applied. These organs assist materially the process of locomotion, the stiff bristles serving to fix one part of the body, whilst the other part is approximated to the fixed portion by muscular contraction.

The head is generally differentiated from the other segments, and in many cases is furnished with eyes, antennæ, and similar organs. The digestive system includes a mouth—provided, in some instances, with a masticatory apparatus, or with a protrusible and retractile proboscis—stomach, and intestine, which latter is usually continued in a straight course to the anus, situated posteriorly. The space (perivisceral space) between the alimentary canal and the walls of the body is divided by a series of vertical partitions (Fig. 42, *h*) into a number of chambers, which communicate inferiorly with each other. The products of digestion (chylaqueous fluid) pass from the intestine into these chambers, and thus circulate throughout the body. By some naturalists this arrangement has been regarded as homologous with the true blood-vascular or circulatory system of higher forms; the so-called dorsal heart, and its connections ("pseudo-hæmal" system), being considered as homologous with the water-vascular system of the Echinozoa.

The dorsal vessel, or heart, which, in the present instance, it may be well to regard as corresponding to the true circulatory apparatus of other forms, consists of an elongated contractile tube, by the wave-like contractions of which the blood is propelled forwards into a main trunk situated on the ventral aspect of the body, and below the nervous cord. From this latter vessel the blood is conveyed by separate vessels to the branchiæ or gills, and, after purification, is returned to the dorsal trunk by vessels running parallel with the partitions which divide the perivisceral space into chambers, as previously described. The blood in Annelida is generally of a red colour, but in certain cases possesses a greenish hue.

The respiratory process is subserved in several forms by the general surface of the body, and by "sacculi," or involutions of the integument. In the higher Annelids, however, distinct respiratory organs, in the form of plume-like branchiæ, or gills (Fig. 40, 3, *d d*), are found, these branchiæ being borne on the dorsal arcs of the segments. The perivisceral spaces appear, also, in a manner to subserve the respiratory function. The nervous system consists of the typical gangliated chain, the anterior ganglia showing a tendency to coalesce together, so as to form a rudimentary "cerebral" mass or brain.

The class Annelida is divided into four orders :—

Order 1. *Hirudinea.* Ex. Leech (*Hirudo*).
Order 2. *Oligochœta.* Ex. Earthworm (*Lumbricus*).
Order 3. *Tubicola.* Ex. *Serpula.*
Order 4. *Errantia.* Ex. *Nereis.*

The two first-mentioned orders are sometimes included under the term *Abranchiate* Annelidans, in allusion to the absence of external branchiæ or gills. These organs being conspicuous in the two latter groups, they are accordingly known as *Branchiate* Annelides.

Order 1. *Hirudinea* (synonyms, *Discophora*, *Suctoria*). The Hirudinea are distinguished by the possession of one or more suctorial and locomotive discs (Fig. 42, *a*, *g*), from which the terms *Suctoria* and *Discophora*, sometimes applied to the group, are derived. No lateral processes exist, these organs, in the present instance, being modified to the greatest extent. The segments of the body are small and closely set. The group is represented by the various kinds of Leeches. The mouth, in the typical and medicinal species, is furnished with a powerful masticatory apparatus, consisting of three triangular and finely-serrated teeth (Fig. 42, *b*), which, together with the anterior suctorial disc, render the leech invaluable for the purposes of the surgeon. A muscular pharynx (*c*) leads into a large and dilated stomach (*d d*), this viscus occupying the greater part of the interior of the body-cavity. From the sides of the stomach, and communicating with it by distinct apertures, a series of blind or imperforate sacs (*e e e*) proceed; these lateral dilatations increase materially the area of the digestive tract, and admit of a large quantity of blood being stored up. From the posterior extremity of the stomach, a short intestine (*f*), terminating in a distinct anus, is given off.

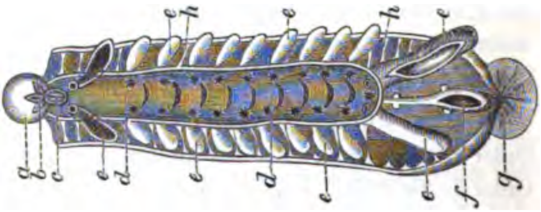


Fig. 42. **Hirudinea.** Anatomy of Leech (*Sanguisuga officinalis*). (Rhymer Jones.)

a, Anterior disc; *b*, teeth; *c*, pharynx; *d*, *d*, cavity of stomach; *e e e e e e*, lateral pouches, the most anterior pair of which is supposed to subserve the function of salivary glands; *f*, intestine; *g*, posterior disc: *h*, *h*, vertical membranous partitions, dividing perivisceral space into chambers.

Respiration is carried on by the general surface of the body, assisted by a number of membranous "sacculi," or pouches, in the walls of the body, over the surface of which the blood-vessels are thickly distributed. These sacculi communicate with the external medium by a series of small openings, or "stigmata."

Of the importance, from a commercial point of view, of the Medicinal Leech (*Sanguisuga officinalis*), nothing need be said. The principal sources of supply are Hungary, Germany, and Russia. The Horse-Leech (*Hæmopsis*) inhabits most of our brooks and streams; it is unprovided with a dental apparatus.

Order 2. *Oligochæta.*—Of this group the Earthworm (*Lumbricus*) may be selected as the most typical representative. As the name applied to this order indicates, the lateral appendages of the body do not, in these forms, reach any great development, either as regards size or numbers. The appendages are not borne on distinct tubercles or processes; they consist of a double row of small bristles, situated on the lateral and ventral aspects of the body. The zones or segments are well marked; and anteriorly, several segments are massed together, forming a thickened zone, connected with the reproductive process, and bearing the name of the "clitellum" or "saddle." The digestive system consists of a mouth, crop, gizzard, and intestine; the hæmal system is modelled after the type of structure of the preceding order, the circulation of fluid through the body, by the perivisceral chambers, being also carried on to great perfection in the present instance. Respiration is effected principally by the general surface of the body, assisted by sacculi or pouches, as in the Leech. The *Naïdidæ*, or Fresh-water Worms inhabiting our ponds and brooks, are also included in this order.

Order 3. *Tubicola.*—The Tube-dwelling Annelides form the first order of the *Branchiata*, in which section the respiratory organs exist in the form of external gills. In the present instance, these organs present a beautifully branched appearance, being situated at the anterior extremity of the body, at which part the lateral appendages are also collected, these latter serving in the Tubicola as tactile organs. The Tubicola possess the power of secreting an external tubular investment in which they enclose their bodies, and from which the technical name of the order is derived. The tubes of these worms vary greatly in composition. Thus, at the

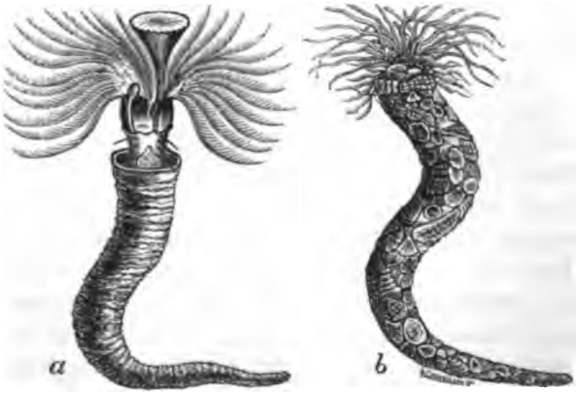


Fig. 43. TUBICOLA.
a, *Serpula contortuplicata*, showing expanded branchiæ and disc.
b, *Terebella medusa*.

one extreme, the *Serpula* (Fig. 43, *a*), a familiar form, secretes a hard calcareous tube, whilst the *Terebella* (Fig. 43, *b*) constructs its habitation of grains of sand, pieces of broken shells, and other heterogeneous substances, which it glues together by aid of a glutinous secretion with which it is provided. The head is but indistinctly marked, the anterior extremity being, however, provided with tentacles and branchiæ, these latter usually arranged in a spiral or crescentic form. The *Serpula* is the best-known example of this group, the hard calcareous tubes of this creature being found on the rocks and stones at low-water mark, whilst the beauty of the branchiæ in the living animal renders its observation and study a matter of great interest. One of the tentacles with which the head of the *Serpula* is furnished, is specially developed, to form a conical plug (Fig. 43, *a*), with which the open extremity of the tube can be closed when the animal has withdrawn into its habitation. The *Terebella*, with its fictitious tube, inhabits the sandy beaches of our coast, and is also a familiar object of the sea-shore.

Order 4. *Errantia.*—The forms included in this group present a great contrast in form and habits to those of the preceding order. The Errantia are free, and, as the term indicates, are characterised by their wandering or errant propensities, these worms being endowed with considerable locomotive powers.

In this group, also, the segmentation is very distinctly marked, and the lateral appendages reach their maximum development, these structures being witnessed in the present instance in their most perfect aspect.

The setæ are well developed, as also are the filamentous cirrhi. The segments of the anterior extremity of the body are for the most part easily recognisable, the head being in general distinctly marked, and furnished with eyes, and "antennæ," or feelers, of which organs usually two pairs are present. The mouth is in some cases provided with a protrusible proboscis (Fig. 44, B), which may be armed with teeth, the stomach and intestine running, as before, a straight course through the body. The gills are large and external, being borne on the sides of the dorsal arcs.

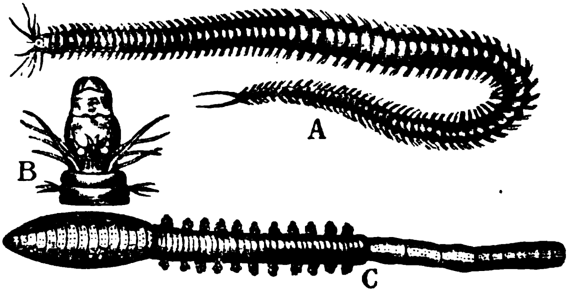


Fig. 44. Errantia.

A, *Nereis*, a familiar "Errant" Annelide. B, Head of *Nereis*, enlarged, to show proboscis, horny jaws, and tentacles. C, *Arenicola piscatorum*, the "lob-worm," showing the branchial or gill-tufts: the lateral appendages are confined to the head.

The *Arenicolidæ*, represented by the *Arenicola piscatorum* or "Lob-worm" (Fig. 44, C), form the first and most familiar of the groups into which the order is divided. This worm somewhat resembles the common Earthworm in general conformation, but it is much larger than the latter worm, and possesses a large rounded head, unprovided with eyes or other organs of sense.

The lateral appendages are small, and are confined to the head, whilst the branchiæ are prominent, and occupy the normal and typical position. The Lob-worm inhabits the sand, burrowing its way under the surface as the tide recedes, and throwing out the refuse-matter of its burrow in the form of coils of sand, which must be familiar to every one who has walked on the sea-beach at low-water mark. The Lob-worm is largely used by deep-sea fishermen as bait. The *Nereidæ* form a very typical group, of which the *Nereis* (Fig. 44, A) may be selected as a familiar representative. The segmentation of the body is, in the present instance, most distinctly seen; the lateral appendages are large and highly developed, and the head is provided with eyes and antennæ. The branchiæ, however, are less distinct than in the previous instance. The Nereis is found under the rocks, stones, and seaweed, on all our coasts. The *Aphroditidæ*, represented by the various species of *Aphroditæ* or "Sea-mice," form the only remaining members of this group worthy of notice. The body in these forms is of oval shape, the back being covered by a series of large membranous and overlapping plates or scales (elytra or squamæ), attached to the lateral processes, and covering the branchiæ, to which water is admitted by the elevation, and expelled by the depression, of these plates. The lateral processes are of large size, and furnished with bristles and spines of corresponding dimensions—the iridescent hues and brilliant lustre of these organs rendering the *Aphrodita* an object of great interest and beauty.

CHAPTER IX.

ANNULOSA—(*Continued.*)

SECTION B. ARTHROPODA.

Arthropoda—General Characters—Classification—Myriapoda.

THE second and higher section of the Annulosa is characterised by the presence of true jointed limbs, articulated to the segments of the body. The typical annulose appearance is in most cases to be distinguished, although it may be greatly modified in certain instances. The Arthropoda generally possess an outer support or "exoskeleton." This is well observed in the chitinous or horny investment of many insects,—such as the Beetles,—or more typically in the hard calcareous "shell" of the Lobster or Crab. This exoskeleton gives firm support to the limbs, and also affords attachment to the muscular system, which, in many members of the group, attains a high degree of development. The digestive system tends to become still more specialised,—a liver and other accessory glands being present in the higher forms. The circulatory system consists of a well-defined dorsal vessel or heart, provided with valves, permitting of the flow of blood in one direction—towards the head—only. The respiratory process is subserved in a variety of ways. In the terrestrial forms breathing is effected by means of air-tubes (tracheæ), which ramify throughout the body, and communicate with the external atmosphere by distinct openings, termed "stigmata" or "spiracles;" or we may find, as in the Spiders, a combined arrangement of tracheæ and pulmonary or lung-sacs. In the aquatic forms we have gills developed, this latter arrangement being witnessed in highest perfection in the Crustacea. The nervous system consists, as before, of a ventral gangliated column, which, however, in certain cases exhibits a decided tendency—exemplified by the Spiders—to become further centred and specialised.

Classification.—The *Arthropoda* are divided into four classes,—*Myriapoda*, *Insecta*, *Arachnida*, and *Crustacea*. On comparing these groups, with reference to their more general characteristics, we find that their differences may be conveniently classed under four heads, namely, as regards—(*a*), the division of the body into its various regions, of head, thorax, and abdomen; (*b*), the number of legs; (*c*), the presence or absence of wings; and (*d*), the nature of the respiratory apparatus.

Thus, in the *Myriapoda* (represented by the Centipedes, Fig. 45), the head alone is distinct, the thorax and abdomen being formed by similar segments, these animals in this respect exhibiting little advance upon the Annelida. The legs are numerous, wings absent, and respiration is carried on by air-tubes (tracheæ).

In the *Insecta* (Fig. 46), the several regions of the body are distinctly marked, the thorax alone bearing the legs, which, in the adult form, never exceed six in number;

wings exist to the typical number of four, these latter being also borne on the thorax, and respiration is performed by means of tracheæ.

In the *Arachnida*, or Spiders, the head and thorax are united to form a single segment, to which the term "cephalothorax" is applied. The legs are now eight in number; no wings are developed; and respiration may be performed by tracheæ alone, by air-tubes in combination with pulmonary or lung-sacs, or by the general surface of the body.

Lastly, in the *Crustacea*, the head and thorax are, as in the preceding class, united to form a "cephalothorax," the legs are more than eight in number, and are borne by the abdominal as well as by the thoracic segments; the respiratory organs exist typically in the form of branchiæ or gills, but the process may be subserved—as in the lower members of the group—by the general surface of the body.

Class I. *Myriapoda.*—The class Myriapoda, as defined above, is of comparatively small extent, being typically represented by the Centipedes (*Scolopendridæ*), and the Millepedes (*Iulidæ*). As the name implies, the number of locomotive appendages is considerable, each segment—in the Millepedes at least—bearing two pairs of jointed limbs. The body is of elongated shape, and the general form and appearance of the Myriapoda may be not inaptly compared to that of a worm, having the segments encased in a chitinous exoskeleton, and provided with jointed limbs. The head is furnished with simple eyes, and with "antennæ" or "feelers," which, in the Myriapoda, never exceed two in number. The mouth is furnished with a masticatory apparatus, allied in structure to that of certain insects.

The Myriapoda are divided into two orders; the *Chilopoda* or "lip-footed" Myriapods, represented by the *Scolopendridæ* or Centipedes; and the *Chilognatha* or "lip-jawed" Myriapoda, of which the *Iulidæ* may be cited as characteristic representatives. The Centipedes possess a poison-apparatus, situated in the neighbourhood of the mouth, and by means of which they are able to inflict severe or even dangerous wounds. A South American species, of considerable size (*Scolopendra gigantea*), is represented at Fig. 45. The *Iulus* or Millepede is a short cylindrical worm-like creature, found under the bark of trees, among damp moss, and in similar situations. It derives its popular name from the immense number of feet with which it is provided. When alarmed the *Iulus* possesses the power of coiling its body into a spiral form, the feet being concealed within the inner coils of the body.

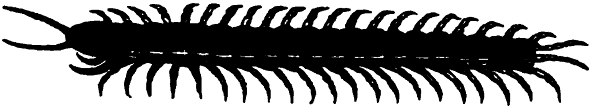


Fig. 45. Myriapoda.
Scolopendra gigantea (reduced).

The Myriapoda resemble the Insecta so closely in many points of structure, that we must refer the reader, for more detailed information of these creatures, to the description of the next class.

CHAPTER X.

ANNULOSA—(*Continued*).

ARTHROPODA. CLASS II. INSECTA.

Insecta—General Characters—Metamorphosis of Insecta.

WHILST agreeing with the general characters of the *Arthropoda*, the *Insecta* present certain peculiarities in structure and conformation worthy of attention and study. The regions of the body are distinctly separated from each other, the three typical portions being readily mapped out. The *head* (Fig. 46, *a*) carries the organs of sense (eyes, antennæ, etc.), and in turn is composed of a definite number (five or six) of segments. The *thorax* is typically divisible into three somites, named respectively, from their position, the *prothorax*, *mesothorax*, and *metathorax*. To the first or anterior segment (*prothorax*), (Fig. 46, *b*), the first pair of legs is articulated; to the middle segment (*mesothorax*), (*c*), the second pair of legs and first pair of wings; whilst the third pair of legs and second pair of wings are borne on the third and posterior segment (*metathorax*), (*d*). The *abdomen* (*e*) consists of various zones or segments, more or less movable upon one another, but unfurnished with locomotive appendages. The whole structure is encased in, and supported by, an exoskeleton, formed of chitinous or horny material.

Commencing with the head or anterior segment, we find the "antennæ" or "feelers" (Fig. 46, *a*) borne on the most conspicuous part. These organs in Insecta never exceed two in number, and are supposed to subserve the sense of touch, although it is highly probable that they may be the seat of other senses. The antennæ vary greatly in form, their shape ranging from a simple rod-like structure, to a branched and most ela-

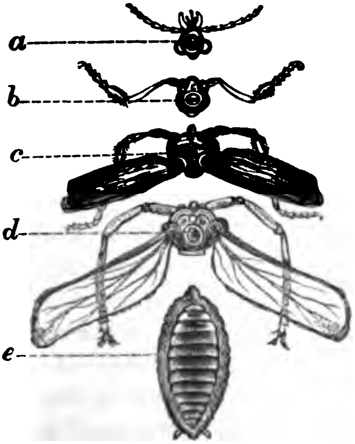


Fig. 46. MORPHOLOGY OF AN INSECT (*Coleoptera*).

a, Head, bearing antennæ and organs of sense; *b*, "Prothorax," or first segment of thorax, carrying first pair of legs; *c*, "Mesothorax," or second segment of thorax, carrying second pair of legs and first pair of wings, which in this case are converted into "elytra" or sheaths, for the protection of the second pair; *d*, "Metathorax," or third thoracic segment, bearing the third pair of legs and last pair of wings; *e*, abdomen, bearing terminal appendages, used for reproduction or as offensive apparatus.

borate and complicated form. In structure they are composed of a number of flexible joints, and they receive an abundant nervous supply from the great nerve-centres of the head. From the antennæ we pass by an easy transition to the organs of vision. These are of very remarkable construction, being for the most part compound in nature. The simple eyes, or "ocelli," with which some insects are furnished, consist each of a simple lens, supplied by a simple nervous filament, and of these "ocelli" two or more may be present. But in the compound eye an enormous number of these minute lenses exist, each lens being furnished with a distinct nervous filament. Each facet is of hexagonal or six-sided shape, and articulates with six similar divisions of the eye. The number of facets thus aggregated together in the masses of the compound eyes, reaches in many cases an enormous extent. Thus, in the eyes of the House-fly, 4000 of these lenses have been calculated to exist; the eyes of the Dragon-fly have been computed to contain upwards of 12,000; whilst the number in some Beetles is said to exceed 25,000.

The mouth, and the various structures entering into the composition of the masticatory apparatus, may be examined next in order. The structure and disposition of parts in the mouth of insects vary greatly throughout the group, but two very obvious and convenient types of structure are to be distinguished; the terms *masticatory* and *suctorial* being applied to these distinct forms of mouth. As the names imply, the former variety is adapted for masticatory purposes, for biting and crushing hard substances on which the insects possessing this type of mouth may feed: the latter is specially suited for suctorial purposes, being adapted to the special requirements of this latter class of insects. Of the first variety the Beetles present characteristic examples, whilst the Butterflies well illustrate the second or suctorial type. The two kinds of mouth, it must be noted, are constructed essentially on the same plan or type, in other words they are homologically similar; the parts in the one variety of mouth corresponding to the parts in the other, though differing in their functional or analogical aspect.

The masticatory mouth consists of four distinct parts; (1), a "labrum," or upper lip (Fig. 47, 1, *a*), bounding the mouth superiorly; (2), a pair of strong jaws, termed "mandibles" (Fig. 47, 1, *b*), which constitute the principal organs in the masticatory mouth; (3), a pair of lesser and supplementary jaws called "maxillæ" (Fig. 47, 1, *c*), the office of which is to further chew and triturate the food; and (4), lastly a lower lip or "labium" (*e*), furnished in most cases with a pair of "palpi" (*f*), or "feelers," and a rudimentary tongue. The "maxillæ" also bear one or two pairs of jointed "palpi," termed "maxillary palpi" (*d*), in contradistinction to those borne by the "labium," and which latter are accordingly named "labial palpi."

In the *Suctorial* mouth the same parts are to be observed, but having undergone certain modifications, to suit them for the change of function. The (1) "labrum" and (2) "mandibles" (Fig. 47, 3, *a*, *b*) are now greatly modified, and appear as mere rudimentary structures. The (3) "maxillæ," on the contrary, are greatly elongated, being drawn out to form a tube of considerable length, termed the "antlia," or "proboscis" (Fig. 47, 2 and 3, *c*), and which is used in sucking up the juices of flowers, upon which these insects principally subsist. Each maxilla is modified to form half of the tubular proboscis, and each half, in turn, forms a sheath for an inner and smaller tube; the "antlia," in reality, thus consisting of three tubes, two being smaller, and contained within the larger one, formed by the union of the maxillæ. The (4)

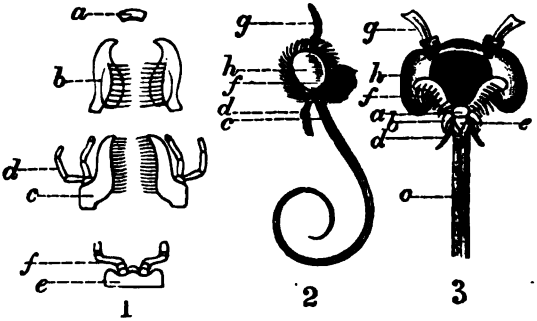


Fig. 47. Mouths of Insecta.

1. Parts of the masticatory mouth of a Beetle; *a*, "labrum," or upper lip; *b*, mandibles; *c*, maxillæ, bearing (*d*) "palpi," or organs of touch; *e*, "labium," or lower lip, also bearing "palpi," (*f*). 2. Suctorial mouth of *Sphinx ligustri*, seen in profile; *c*, spiral proboscis or "antlia," formed by the elongated maxillæ; *d*, maxillary palpi; *f*, labial palpi, greatly enlarged, and modified to form protective organs for the proboscis (*c*); *g*, antenna; *h*, eye. 3. Head and mouth of *Sphinx* viewed from before (the figures refer to the corresponding parts in 1 and 2); *a*, labrum; *b*, abortive mandibles; *e*, labium.

"labium," or lower lip (*e*), is also present, and the "labial palpi" (Fig. 47, 2 and 3, *f*) are developed to form rounded cushion-like organs, between which the "antlia," when at rest, is coiled up.

Various forms of mouth, occupying, structurally, an intermediate position between these two principal varieties, exist, these latter partaking of the nature of both of the typical forms. Thus, in the Bees and their allies, a characteristic combination of the masticatory with the suctorial mouth is found. The "labrum" and "mandibles" retain their original size, the latter being employed as true masticatory organs; the "maxillæ" and "labium" are, however, modelled after the suctorial type, the former organs being modified to form a proboscis, and the latter as protective sheaths for the elongated "maxillæ." This compound mouth is eminently adapted to the life and habits of these insects, the masticatory organs being employed in the construction of their nests and habitations, whilst the suctorial organs are used in the collection of the flower-juices upon which these insects live. In the Bugs, and also among the *Diptera*, represented by the House-fly, other modifications of the structure of the mouth, adapted to the particular habits of the several forms, take place, but these are not of sufficient interest to necessitate description in the present instance.

Passing from the consideration of the segments of the head to those of the thorax, we find the anterior segment ("prothorax") of this region bearing the first pair of legs. The leg of an insect consists of various definite parts. Thus the first, or proximal joint, is termed the "coxa," or hip. This segment articulates with the thorax by a universal joint which permits of free movement in almost any direction. To the "coxa" succeeds the "femur," or thigh, and next in order succeeds the "tibia," corresponding to the leg of the higher animals. The "tarsus," or foot, forms the distal portion of the limb, and this latter division may consist of one, but usually of several small segments. The terminal segments are provided with a variety of organs assisting insects in locomotion. Thus, in some species, hooked appendages terminate the limbs, or—as in the case of the House-fly—a curious arrangement of membranous plates, furnished with sucking discs, exists, the insects being enabled by these means to walk and retain their position on any surface, however plane or smooth. The "mesothorax," bearing the first pair of wings and the second pair of legs, introduces us to the consideration of the wings, their modifications, and structure. The typical number of wings in the Insecta is four; but these organs may be greatly modified, or may vary in number, the structure and arrangement of the wings affording the basis for the classification of the group. In structure, the wings are composed of two layers of delicate membrane, between which supporting ribs or "nervures" are situated. The "nervures" are, in many cases, hollow, and thus form tubes, to which air is admitted from the respiratory organs, the result of this arrangement being the due inflation of the wings, and their consequent and more perfect adaptation to the purpose of flight. The modifications which these organs undergo may be summed up under the two heads of number and conformation. In the *Diptera* (Fig. 53, *c*), represented by the House-fly, only two wings (the anterior pair) exist, the place of the hinder pair being supplied by two filamentous bodies, to which, from a supposed use in balancing the creature, the name of "halteres," or "poisers," has been applied. Again, in the *Apterous* Insects (Fleas, etc.), as implied by the name of the group, no wings are developed. As regards conformation, whilst the majority exhibit the ordinary structure above described, certain forms present deviations from the usual type of structure. Thus, in the *Coleoptera*, or Beetle-tribe, the anterior pair of wings, which are generally the larger, are converted into horny sheaths, termed "elytra" or "wing-cases," beneath which the posterior pair are covered and protected. In the *Orthoptera*, represented by the Crickets, Grasshoppers, and their allies, the anterior pair of wings are smaller than the hinder pair, and also form "elytra." Lastly, in the *Strepsiptera*, a small and unimportant division of the class, the anterior wings are rudimentary, their place being supplied by a pair of small twisted filaments, from the presence and nature of which the term "Strepsiptera," or "twisted-winged" insects, is derived. The "metathorax," or posterior segment of the thorax, comes last in order, this somite bearing the posterior pair of wings, and the third and last pair of legs.

The abdomen gradually tapers towards its posterior extremity, which in many cases is furnished with organs, connected with reproduction and the deposition of eggs, or which may serve as offensive weapons. In the Ichneumon-fly, Saw-fly (Fig. 55, *a*), and many other insects, the abdominal appendages exist in the form of ovipositors, or sharp, spear-like filaments, which are used in the excavation of cavities, in which the eggs are deposited. In the Bee and its allies, these terminal organs take the form of a sting; whilst the *Poduræ*, or "Spring-tails," are provided with elastic bristles, by means of which they are enabled to take considerable leaps, this circumstance giving rise to the familiar name of these creatures.

The digestive system of insects comprises the elaborate mouth already described, and from which the œsophagus or gullet (Fig. 48, *b*) is continued. Before entering the true stomach, the gullet expands into two dilatations, the first of which is termed the "ingluvies," or "crop" (Fig. 48, *c*). This cavity appears to exercise but little digestive power over the food, its function being, in all probability, limited to serving as a temporary receptacle for the masticated nutriment, previous to its being passed onwards to the second dilatation or "gizzard" (*d*). The walls of this latter cavity are of considerable thickness, and of corresponding muscular power. Horny plates or teeth are developed in the lining membrane of the cavity, and by the action of these organs the food is bruised and triturated, and otherwise prepared for the third cavity, the true "chylific stomach" (*e*), to which it is next in order consigned. From this latter cavity an intestine (*g h*, *k*) of variable length is given off: the intestine being comparatively short and widened in the carnivorous or flesh-eating insects, and of greater length and convoluted in those which feed on a herbivorous or vegetable diet. The intestine terminates in a "cloaca" (*n*), or chamber, which also receives the terminal ducts of the urinary (*m*) and generative organs. Salivary glands are very generally present, but seem to reach their highest development in those insects which possess suctorial mouths. The liver is represented by a series of tubular organs (*f*), which open into the intestine immediately below its origin from the posterior extremity of the stomach. The renal or urinary function is in like manner subserved by several blind or cæcal tubes (*m*), which enter the rectum or large intestine close

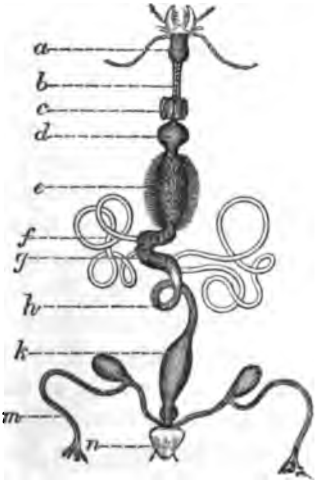


Fig. 48. Digestive System of a Beetle.

a, Pharynx, above which the mandibles and antennæ are represented; *b*, gullet; *c*, crop; *d*, gizzard; *e*, true, or chylific stomach; *f*, biliary, or hepatic tubes, subserving the function of a liver; *g h*, intestine; *k*, large intestine or rectum; *m*, renal vessels, opening, with the efferent ducts of reproductive and digestive systems, into the "cloaca" (*n*).

above its termination in the "cloaca." No true absorptive system exists, the products of digestion passing through the walls of the alimentary canal, and thus circulating through the sinuses or spaces which exist between the various organs. No defined system of closed blood-vessels has been found, the blood flowing through the system by the sinuses or "inter-visceral" spaces just mentioned. The circulatory system is represented by a tubular, contractile, dorsal vessel, furnished with valves, which permit of the flow of blood in one direction only—namely, towards the head, or anterior extremity of the body. The blood, entering the heart through valvular apertures in its substance, is propelled by the contractions of the organ towards the head, reflux being prevented by the valves, which open towards the anterior extremity only. Escaping from the heart at the head, the blood once more circulates throughout the systematic sinuses, to be returned to the heart for recirculation.

During the systemic circulation of the blood, it is exposed to the action of the respiratory system, which consists of a series of tubes, ramifying throughout the body, and to which the name of "tracheæ" has been applied. Air is admitted to the respiratory system by a definite series of openings situated on the sides of the body, and termed "stigmata" or "spiracles" (Fig. 49, B, *a b*). These apertures, in many cases, are furnished with membranous valves or muscular apparatus, by means of which the orifices can be closed at the will of the creature. The "spiracles" open directly into main trunks or tracheæ, which subdivide into smaller branches—a complete and connected network of air-tubes being thus formed within the body of the insect. The "tracheæ" are composed of two membranes, between which an elastic spiral filament (Fig. 49, A) is coiled up. By this means the air-tubes are kept tense and open, this arrangement at the same time ensuring the necessary amount of flexibility and adaptation to the movements of the creature. Air is thus introduced throughout the entire body of the insect, and the animal rendered light and buoyant for flying. The importance of this arrangement in assisting the muscular movements of the animal, will also be readily appreciated. The wings appear by their motion to indirectly subserve the respiratory process—air, as previously observed, being admitted to these organs through the hollow "nervures" or supporting ribs.

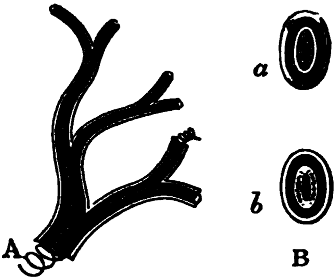


Fig. 49. Respiratory Apparatus of Insecta.

A, Part of an air-tube (*trachea*), showing the spiral fibre. B, Spiracles or stigmata: *a*, closed; *b*, open.

The nervous system of insects is constructed on the typical annulose plan, previously described. The "cephalic" or head ganglia, in particular, are largely developed—the large optic nerves supplying the eyes being derived from this centre.

Metamorphosis of Insects.—In the course of development, and before attaining the mature and adult form, insects pass through a series of more or less completely-defined changes, to which the term "metamorphosis" is applied. When winged and fully grown, the insect, as a rule, does not increase materially in size or bulk, and hence we find that a set period exists, during which the whole energies of its being are devoted to its nourishment; the life of the perfect insect, on the other hand, being mainly devoted to the reproduction of the species. Whilst exhibited to great perfection in certain orders of insects, the metamorphosis may in other instances be considerably modified, and in other cases, no metamorphosis whatever may be undergone. Accordingly, and so far as their metamorphosis is concerned, insects may be classified in three groups or divisions :—

I. *Holometabola.*
II. *Hemimetabola.*
III. *Ametabola.*

I. *Holometabola.*—The Holometabolic insects are those which undergo a "complete" metamorphosis, and thus exhibit the process in fullest perfection. Of this section the Butterflies and Moths (*Lepidoptera*), may be cited as familiar and typical examples; and in the development of such forms three defined stages are observed. These, commencing with the first in order of development, are named—(*a*) *Larva;* (*b*) *Pupa* or *Chrysalis;* and (*c*) *Imago.* From the egg comes forth the larva, grub, or caterpillar (Fig. 50, *a*), as it is familiarly termed—a worm-like creature, usually furnished with a number of short, stunted feet, some of which represent the true legs of the future and perfect insect, whilst others of its locomotive appendages are merely characteristic of, and belong solely to, the larval stage of its existence. The whole life of the larva is devoted to its nutrition, the caterpillar eating in the most voracious manner, and effecting great devastation among plants and flowers, by thus injuring and destroying the leaves. So rapidly does it increase in size that it moults or changes its skin many times during this stage of its existence, to accommodate the increasing bulk of its body; the process of moulting being technically known as "ecdysis." A masticatory mouth,

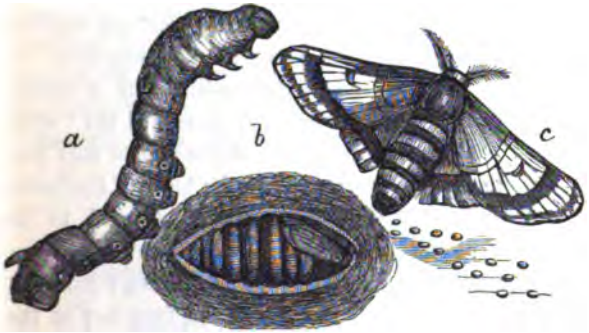


Fig. 50. METAMORPHOSIS OF INSECTA.

Holometabolic or complete metamorphosis of Silk-moth (*Bombyx mori*); *a*, "larval" stage; *b*, "Pupa" stage, showing pupa enclosed in cocoon; *c*, "Imago," or perfect insect.

suited for biting and triturating the substances upon which the larva feeds, is also characteristic of this stage. After spending a longer or shorter period in the larval form, the embryo enters upon the next or "pupa" stage (Fig. 50, *b*), which is as characteristically marked by quiescence, as the preceding stage was by activity and movement. It now lies inert and motionless, or may enclose its body in a "pupa-case" or "cocoon" of silky material, furnished by a special gland situated on the "labium," and termed the "spinneret." Within the pupa-case development still proceeds, changes being wrought in the body of the larva, and for which the preceding period, devoted to its nourishment and growth, has fully prepared it. After the required time has elapsed, there comes forth from the pupa-case a form entirely different from any of the preceding—a perfect creature, furnished with wings, adapted for an aërial existence, and known as the "Imago," or perfect insect (Fig. 50, *c*). Two defined periods may thus be discerned in the above process. The first of these, termed the *Nutritive* period, is constituted by the larval stage of the insect's existence. During this period, as previously remarked, the energies of the creature are devoted solely to its nutrition and growth. The second may be named the *Reproductive* period, and is constituted by the life of the Imago, or perfect insect, which, as in the case of the Butterflies, is characterised by the active preparation for the deposition of eggs, and for the other habits connected with the reproductive process. The ephemeral existence of these creatures in the adult form, renders such an arrangement of their life-period necessary, the special divisions above enumerated being distinguished, each, by its peculiar and characteristic phases.

II. *Hemimetabola.*—In the Hemimetabolic or "Incomplete" metamorphosis, exemplified by the Grasshoppers, Locusts, etc., three stages are also to be distinguished, but these differ widely from those of the preceding division. The chief and essential difference between the Larva (Fig. 51, *a*), and Imago (*c*) of Hemimetabolic insects, consists in the absence of wings in the former and primary stage; these organs appearing in the intermediate, or Pupa stage, as small lobes (Fig. 51, *b*), situated on the posterior part of the thorax. The larva and pupa are equally active, the quiescent stage

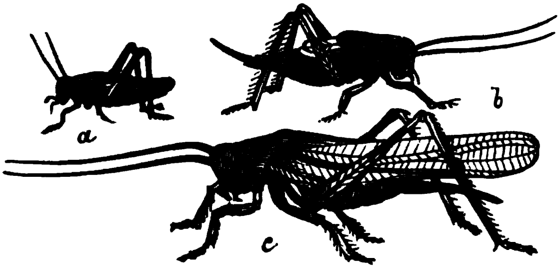


Fig. 51. METAMORPHOSIS OF INSECTA.

Hemimetabolic or Incomplete Metamorphosis of Grasshopper (*Gryllus viridissimus*): *a*, "Larva;" *b*, "Pupa," in which the wings are beginning to appear as lobes on the posterior portion of the thorax; *c*, "Imago," or perfect insect, characterised by the possession of fully-developed wings.

of the complete metamorphosis being exchanged in the present instance for one of active movement. Modifications of this form of metamorphosis are met with in some few cases, the most interesting of which occur in the development of the May-flies and Dragon-flies, in which insects the larvæ are aquatic in their habits, and do not resemble the perfect insect so closely as is the case generally with Hemimetabolic forms.

III. *Ametabola.*—These insects do not undergo any metamorphosis, the larva resembling exactly the perfect insect, and only increasing in size to the required extent. The insects included under this latter division belong to the *Apterous* or "wingless" orders, of which the various kinds of Lice may be cited as examples.

CHAPTER XI.

ANNULOSA—(*Continued.*)

Classification of Insecta.

THE class Insecta is divided into twelve orders, distinguished from each other principally by the form, structure, and arrangement of the wings. Other features in the economy of insects may, however, be taken into consideration in classifying the group; thus, the structure of the mouth, and the metamorphosis, may also be employed to aid in expressing the relations of the various members of the class.

The Insecta are conveniently divided, by the differences in their metamorphosis, into the three groups already described, the *Holometabola*, *Hemimetabola*, and *Ametabola;* and under each of these three divisions various orders, bearing certain relations to each other, are comprised.

Section A. *Ametabola.*—The insects included in this division do not undergo a metamorphosis—they are *Ametabolic.* They are also destitute of wings; and from this latter circumstance the three orders of this section are sometimes termed the *Apterous* or "wingless" Insecta.

Order 1. *Anoplura.*—The various kinds of Lice (*Pediculi*) form typical representatives of this order. The body is flattened, and the legs are armed at their extremities with short claws. The head is distinctly marked, and bears several simple eyes or "ocelli." The mouth is constructed on the suctorial type, but is also furnished with sharp bristle-like organs, which are analogous to the mandibles of the masticating mouth.

Order 2. *Mallophaga.*—As implied by the technical name of this order, the insects included in it are also parasitic in their habits, and feed on the epidermal coverings of their hosts. The Bird-lice (*Philopteri*) are the most familiar examples of the group. These insects live principally upon birds, although some species infest mammals also. They cause the destruction of the soft feathers and down of birds, which they eat and attack by aid of the masticatory organs with which their mouths are furnished.

Order 3. *Thysanura.*—The Thysanura possess certain caudal or tail appendages, by means of which they are enabled to make considerable leaps—a circumstance which has given rise to their common name of "Springtails." The *Podura*, a small insect, inhabiting damp situations, such as underground cellars, is the typical example of the order. The body is slightly elongated, and is covered by plates or scales, which, under the microscope, present a beautiful white or pearly lustre. The extremity of the abdomen is furnished with two slender filaments, arranged in a fork-like manner, and by the sudden extension and elasticity of these filaments, the insect is enabled to spring with great force and to a considerable distance. The mouth is masticatory, and simple eyes are generally present.

Section B. *Hemimetabola.*—The three orders of this section are characterised generally by their undergoing the "Incomplete" form of metamorphosis, the chief peculiarity of which consists in the pupa being active or capable of movement, and in the larva bearing a close resemblance to the perfect insect, but differing from it in not possessing wings, which are thus characteristic of the adult form.

Order 4. *Hemiptera.* — The wings of Hemipterous insects are four in number, and for the most part membranous ; in one section of the order, however, that of the *Heteroptera* or "dissimilar-winged," the inner half of each anterior wing is rendered hard and solid by the deposition of chitinous or horny material, and from this latter peculiarity the section has received its technical designation. The mouth is formed on the suctorial type, but the mandibles and maxillæ exist in the form of sharp bristle-like organs, by means of which these insects inflict punctures or wounds in the bodies of other animals.

The Hemiptera are subdivided into two sub-orders, in the first of which—that of the *Homoptera* or "similar-winged" insects—the Cochineal-insect (*Coccus*), of commercial repute, the "Plant-lice" (*Aphides*), and the *Cicadas*, are included. The anterior wings in this section are entirely membranous. The Cochineal-insect is of great commercial importance, as furnishing some of our finest red dyes, and also the substance known as shell-lac, and which is extensively used in the arts and manufactures. The *Coccus* forms an exception to the metamorphosis of this division, in that it undergoes a *Holometabolic* or complete metamorphosis. The *Aphides* are but too well known, from the destructive effects which they produce in our nurseries and gardens—the hop, amongst many other plants, suffering especially from their visitations.

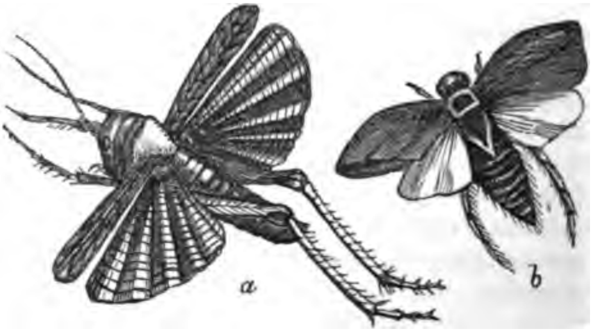


Fig. 52. HEMIPTERA AND ORTHOPTERA.

a, Common locust (*Locusta*), an Orthopterous insect; *b*, "Water-boatman" (*Notonecta*), exemplifying the order Hemiptera, and showing the anterior chitinous wings.

The *Heteroptera*, forming the remaining sub-order, are distinguished by the modification of the wing-structures previously mentioned. The various kinds of bugs exemplify this subordinate group. The Land-bugs (*Geocores*), and the Water-bugs (*Hydrocores*), represented by the Water-fly or Water-boatman (*Notonecta*), (Fig. 52, *b*), may be cited as typical representatives of this sub-order.

Order 5. *Orthoptera.*—In this order are included the Locusts (*Locustina*); Crickets (*Achetina*); Grasshoppers (*Gryllina*); and allied forms. The anterior wings are of a coriaceous or leathery consistence, thus forming "elytra," or "wing-cases," for the protection of the posterior pair, which are folded longitudinally, or after the manner of a fan. The mouth is of the masticatory description, and of very powerful construction.

The Orthoptera are divided into two sections, distinguished by the conformation and corresponding use of the legs. In the first group, the legs are formed for running, and are of nearly equal size throughout. Under this first subdivision are included the Cockroaches (*Blattina*) and Earwigs (*Forficulina*), these and allied forms being known as *Cursorial* Orthoptera. In the second group the hinder legs are developed to a great extent, enabling the insects to leap with great ease and power. These latter are accordingly termed *Saltatorial*, or leaping Orthoptera; and of this section the Locusts (Fig. 52, *a*), Crickets, and Grasshoppers (Fig. 51, *c*), form typical examples.

Order 6. *Neuroptera.*—The wings of *Neuropterous* insects are of large size, wholly membranous, and exhibit a peculiar reticulated or net-work appearance, caused by the interlacing of the numerous "nervures" which support the membrane; this latter peculiarity suggesting the technical name of the order. The mouth is masticatory.

The order is represented by the Dragon-flies (*Libellulidæ*), (Fig. 53, *a*), May-flies (*Ephemeridæ*), and White-ants (*Termitidæ*). The Dragon-flies are exceedingly active and voracious in their habits, the larva and pupa being aquatic. The pupa is provided with a peculiar arrangement of the lower lip, consisting of an elongated shaft, with two movable segments or jaws attached to its free extremity, this apparatus constituting a powerful prehensile organ, by means of which the pupa is enabled to seize the insects and larvæ upon which it exists. When at rest, this organ is applied to the front of the head, covering the anterior part closely, and giving rise, from its appearance, to the term "mask," which has been applied to it. Respiration, in the transitory stages of the Dragon-fly's existence, is per-

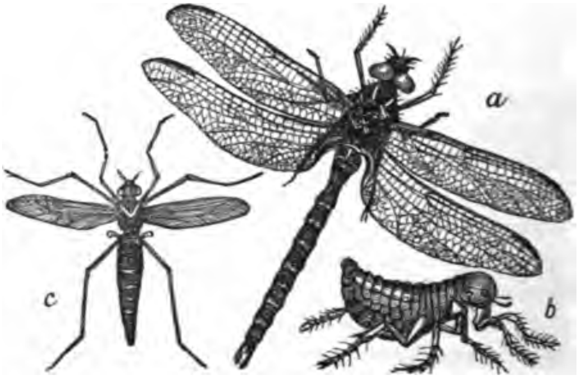


Fig. 53. NEUROPTERA, APHANIPTERA, AND DIPTERA.

· *a*, Dragon-fly (*Libellula cancellata*); *b*, Flea (*Pulex irritans*); *c*, Crane-fly (*Tipula oleracea*), showing posterior filaments (*halteres*).

formed by the admission of water within the body, thus bathing the air-tubes, and providing for the due aëration of the blood. After passing the required period in this aquatic case, the imago emerges and enters upon an active and aërial existence, leaving the pupa-skin usually attached to the stems of aquatic plants. The *Libellulidæ* thus, in their metamorphosis, approach more closely than other Hemimetabolic forms to the Holometabola—the larva and pupa bearing less resemblance to the perfect insect than is generally the case with the embryonic stages of the present series. The May-flies (*Ephemeridæ*) derive their technical name from their brief and short-lived existence. The larva and pupa (as in the preceding case) are aquatic, these forms being provided with curious gill-tufts, for the purpose of respiration.

The *Termitidæ* or White-ants—to be carefully distinguished from the ordinary Ants, which belong to the *Hymenoptera*—form typical examples of social insects, these creatures living in communities, composed of various classes or grades of individuals, and duly regulated by fixed laws. The Termites inhabit the tropical regions of the world, and construct habitations, usually of conical shape, and composed of earthy material consolidated and cemented firmly together by the ants. Internally, the nest, which attains a height of five or six feet, is divided into various suites of chambers, set apart for distinct and special purposes; the royal apartments, chambers for the attendants, nurseries, and storehouses, being thus partitioned off. A king and queen govern each community, and are alone capable of producing fertilised ova. The rest of the community are divided into two classes—"Working-ants," on which devolve the care of the young, and the construction and repair of the nest; and secondly, "Soldier-termites," furnished with powerful jaws, for the defence and protection of the community.

Section C. *Holometabola.*—The metamorphosis in this section is of the complete variety; the larva being free and the pupa quiescent.

Order 7. *Aphaniptera.*—The Fleas (*Pulicidæ*) (Fig. 53, *b*) may be cited as typical representatives of this order, in which the wings are rudimentary, existing in the form of small plates or lobes on the thoracic segments.

The mouth is suctorial, but is furnished with lancet-shaped mandibles, whilst a sharp styliform filament, used for piercing the skin of the animals upon which these insects exist, is also found.

Order 8. *Diptera.*—The wings in this group, as the term *Dipterous* would imply, are two in number, the posterior pair being rudimentary, and represented by two filamentous appendages, supposed to be of service in balancing the insect, and hence called "halteres" or "poisers" (Fig. 53, *c*). The prothorax is usually small, and of limited size, whilst the head segments are large and well-developed. The mouth is suctorial, but may also exhibit certain modifications from the typical plan of structure.

The various kinds of Flies (*Muscidæ*) and Gnats (*Cu-*

licidæ) represent this order. The larvæ are familiarly known as maggots, the eggs being deposited in decaying and putrefying organic matter, of which these insects are accordingly the great destroyers and removers. The pupæ generally lie quiescent within the larval skin. The Crane-fly (*Tipula*), represented at *c*, Fig. 53, exemplifies this order.

Order 9. The *Lepidoptera.*—The *Lepidoptera*, represented by the butterflies and moths, are distinguished by the possession of four large membranous wings, which are covered by minute plates or scales, arranged in an imbricated or overlapping manner; and from this circumstance the term *Lepidopterous*, or "scale-winged" insects, is applied to this group. The mouth is eminently suctorial, and the complete form of metamorphosis is seen in greatest perfection amongst these insects. The *Lepidoptera* are divided into two natural groups, distinguished by their habits, as regards the period of the day at which they appear and fly about.

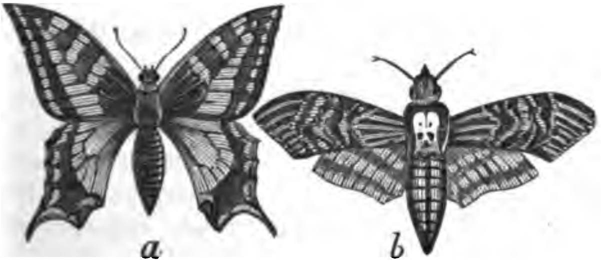


Fig. 54. LEPIDOPTERA.

a, *Papilio machaon*; *b*, "Death's-head" Moth (*Acherontia atropos*).

The *Diurnal* or Day *Lepidoptera*, represented by the Butterflies (Fig. 54, *a*), represent the first of these groups; whilst the Moths, constituting the *Nocturnal Lepidoptera* (Fig. 54, *b*), form the second division.

The Lepidoptera are sufficiently familiar, in form and appearance, to preclude the necessity of referring to their general description. The beauty and variety of colour displayed throughout the order excite our warmest admiration, whilst their active habits and graceful movements harmonise effectively with their gay appearance.

The larva is generally of worm-like form, and is normally composed of thirteen segments. It is provided with a mouth fitted—unlike that of the perfect insect—for mastication, the mandibles being specially developed, and constituting powerful and efficient instruments for chewing and triturating the leaves and vegetable substances on which the caterpillars feed. On the "labium" is situated the tubular "spinneret," or organ by which the silky material, used in constructing the "cocoon," is formed into threads, and otherwise prepared for the formation of the "pupa-case;" the viscid secretion itself being furnished by two glands situated internally, and with which the "spinneret" communicates. When engaged in constructing the "cocoon," this silk-secretion is pressed out through the aperture of the "spinneret," and, by exposure to the air, becomes more tenacious and of a firmer consistency, and in this form is drawn out as a long slender thread. The thoracic segments of the larva bear six legs, the feet of which are furnished with claws; these thoracic legs represent the true legs of the perfect insect. The abdominal segments also bear a variable number of short stunted legs, of fleshy consistence, and to which the term "pro-legs" has been applied. The caterpillar, as previously described, feeds voraciously on leaves and the soft tissues of plants, and at the proper period retires to some sheltered situation, enclosing its body within the "pupa-case," which it manufactures from the silk-secretion. The quiescent or pupa-state, although marked by no outward or visible signs, is nevertheless characterised by the development within the case of the perfect form, which, in due course, emerges from the cocoon, to enter upon a new and aërial existence.

The Silk-moth (*Bombyx mori*) (Fig. 50) is certainly the most important member of this group. The larva invests its body with a cocoon, composed of the silk-material, and in this it passes the pupa-stage of its existence. The pupa is killed before it pierces or injures the cocoon, and the silk is then unwound as a long delicate thread.

The larvæ of the Leaf-rolling *Lepidoptera* (*Tortricina*) construct pupa-cases by rolling up the edges of leaves; and the Clothes-moth (*Tinea sarcitella*) weaves from the fibres of cloth an investing cocoon, in which it passes the pupa state.

Order 10. *Hymenoptera.* The wings of the Hymenoptera are four in number, and are provided with but few "nervures," whilst these may, in some cases, be entirely absent. The mouth is of compound structure, combining the essential parts of the masticatory and suctorial types, and the extremity of the abdomen is generally furnished with appendages, the functions of which may, however, vary. Thus, in the case of the Saw-flies (*Phyllophaga*), (Fig. 55, *a*), these appendages take the form of saw-like organs, used for cutting grooves in the bark of trees, in which situations the eggs are deposited; or in other forms the ovipositor may assume the form of a boring organ (*terebra*); whilst in a third variety (Bees), the appendages are modified to constitute a "sting" (*aculeus*).

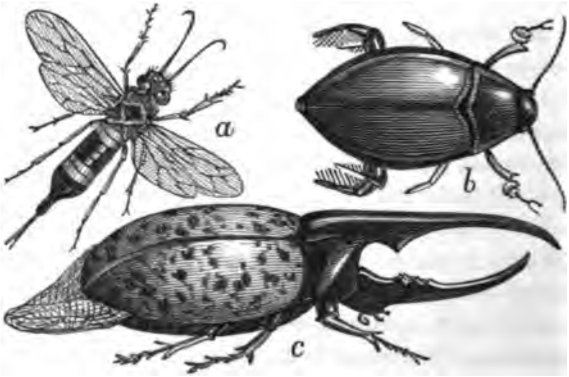


Fig. 55. HYMENOPTERA AND COLEOPTERA.
a Saw-fly (*Sirex gigas*); *b*, Water-beetle (*Dytiscus marginalis*); *c*, "Hercules beetle" (*Dynastes Hercules*).

The *Hymenoptera* are represented by Bees (*Apidæ*); Wasps (*Vespidæ*); Ants (*Formicidæ*); Gall-flies (*Cynipidæ*); etc.

The Bees, Wasps, and Ants, are well known for their social habits. A bee-community consists of three distinct grades or sections,—the males, females, and neuters. There is usually but a single queen in each hive, and she produces the many eggs from which the succeeding generation is born. The males, or drones, are produced during the summer season, and after impregnating the female, die, or are ejected from the hive. The workers, or neuters, as they are termed, perform the labour of the hive, and also, at the appropriate season, tend and nourish the young progeny.

The Ants have long typified industry and economy, and an examination of their habits and mode of life amply justifies the high place they hold in the estimation of the poet and philosopher. The colony of ants is made up, like that of the bees, of males, females, and neuters,—the latter being, it is supposed, females in an imperfect state of development. The labours of the neuters in providing for the wants of the other members of the community, and the great instinct exhibited in the performance of all their duties, would seem to indicate a near approach to the higher sense of reason itself. Certain species of ants, it is further said, capture the pupæ of other species, and train these latter up as slaves and attendants; the labour and work of the community, in these cases, devolving upon the foreign and enslaved servitors. The Saw-fly (*Sirex*) (Fig. 55, *a*) is so named from the possession of the saw-like appendages before alluded to. The Gall-flies (*Cynips*) are to be regarded as important from a commercial point of view, inasmuch as, from the punctures made in the oak and other trees, by the ovipositors of these insects, the excrescences known as "galls" spring forth. The larva is contained within the "gall," on the substance of which it feeds. The "galls" of the oak are those most esteemed for commercial purposes.

Order 11. *Strepsiptera.*—This order merely requires mention. It is of very limited extent, and includes but a few forms, found parasitic on Bees, Wasps, and other *Hymenoptera.* The males alone are winged and active, and the anterior wings are rudimentary, their place being supplied by a pair of curious twisted filaments, from the possession of which the technical name of the order is derived.

The *Stylops*, or Bee-parasite, is the most familiar form of this order. The female exists in the form of a footless grub, furnished with a horny head, which protrudes from between the abdominal segments of the infected bee. The larvæ exist within the body of the female, and upon attaining their full size they escape from the body of the parent, to attach themselves in turn to another host. Should the larva, however, be a male, it becomes a pupa within the larva-skin, and from this case it emerges as the free, winged, and perfect insect.

Order 12. *Coleoptera.*—In this order, of which the Beetles are the typical representatives, the anterior wings are of horny consistence, and form sheaths or "elytra" for the membranous posterior pair, which are thus alone serviceable for flight. The mouth is of the masticatory description, and exhibits that type of structure in the most perfect degree; whilst the hard chitinous exoskeleton is also seen to advantage in the present instance.

The common Water-beetle (*Dytiscus marginalis*), represented at *b*, Fig. 55, and the *Dynastes Hercules*, or "Hercules beetle" (Fig. 55, *c*), afford examples of this group. In both figures the hard "elytra" are shown, the wings being concealed by these "cases."

The number of species included within the limits of this order is very great. The Coleoptera are, for the most part, rapacious in their habits, feeding principally on decaying vegetable and animal matter, and thus acting as important agents in the removal of noxious and putrefying material.

CHAPTER XII.

ANNULOSA—(*Continued.*)

ARTHROPODA. CLASS III. ARACHNIDA.

General Characters of Arachnida—Classification—Trachearia—Pulmonaria.

THE class *Arachnida*, although essentially distinct from that of the *Insecta*, possesses many characteristics in common with the latter group; whilst its affinities to the higher division—that of the *Crustacea*—are still better marked. So far as regards their general characteristics, the *Arachnida* are distinguished (*a*), by the union of the head and thoracic segments to form a "cephalothorax;" (*b*), by the number of legs, which in the adult state never exceed eight in number, these organs being borne by the thoracic segments only; (*c*), by the absence of wings; and (*d*), by the nature of the respiratory apparatus, which typically consists of a series of pulmonary or lung-sacs, combined with tracheæ, or air-tubes. No true antennæ are found in Arachnidans—although analogous organs appear to exist—and the eyes are simple in structure. The integument may be horny over its entire surface, as in the Scorpions; or partly chitinous and partly soft, as in the Spiders, in which the cephalothorax is protected by a horny investment, the abdomen remaining soft; whilst, in other forms, the skin may be entirely soft and unprotected.

The class is typically represented by Spiders and Scorpions, but Mites, Ticks, and several allied forms, are also included in the group.

The legs are normally composed of seven joints, and are usually terminated by claws. The feet are in most cases also furnished with hairs, bristles, and similar appendages—these organs assisting the animal in retaining a firm hold of any surface, and, in the web-spinning forms, aiding in the manufacture of the net.

The digestive canal is generally short, the mouth being furnished with two pairs of jaws, termed, as in insects, mandibles (Fig. 56, A *m*), and maxillæ (*c*). The mandibles of *Arachnidans* are supposed to be the homologues of the antennæ of the other divisions. Each mandible, in the Spiders, bears at its free extremity a hook-shaped claw or fang (Fig. 56, C, *a*), perforated by a canal (*c*), opening at the point of the fang, and communicating internally with a poison-gland (*d*), situated at the base of the mandible. The maxillæ are provided with greatly developed palpi (Fig. 56, A, *p*), which, in the male Spiders, are intimately connected with the reproductive system, but which, in the females, are merely terminated by hooked processes. In the Scorpions, the maxillary palpi are terminated, in both sexes, by simple hooks. In the lower forms (Mites, etc.), the mouth is constructed after the suctorial type, and is suited for the imbibition of the fluids upon which these creatures subsist. The œsophagus is short, and leads into a compound stomach, consisting of four membranous sacs, each of which appears to prepare the food, in some degree, for the succeeding organ. The intestine, continued from the stomach in a straight course, terminates in a common chamber or "cloaca," which also receives the ducts of certain tubular organs, supposed to subserve a renal or urinary function. Salivary glands and a liver-mass are also in most cases to be discerned.

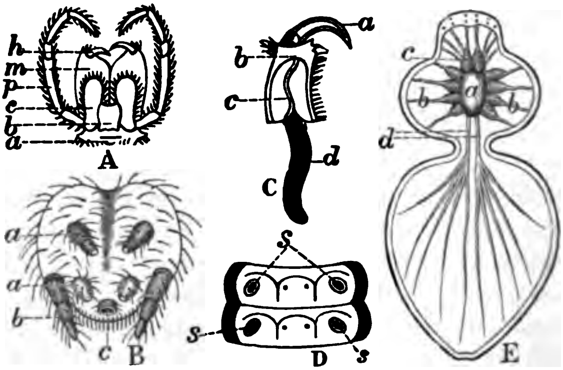


Fig. 56. Morphology of Arachnida.

A, Parts of the mouth of Spider: *a*, sternum; *b*, labrum; *c*, maxillæ; *m*, mandibles; *p*, maxillary palpi; *h*, mandibular hook or fang. B, Spinning apparatus of Spider: *a a*, spinnerets; *b*, filiform appendages; *c*, anus. C, Poison apparatus of Spider: *a*, hooked claw situated on (*b*) the mandible; *c*, canal, leading through the mandible from the poison-gland (*d*), to the fang (*a*). D, Under-surface of two segments from abdomen of Scorpion, showing at *s s* the "stigmata," or openings of the pulmonary sacs. E, Nervous system of Spider (Jones): *a*, large nervous mass representing the united abdominal ganglia; *b b*, thoracic ganglia; *c*, encephalic or optic lobes, supplying the head and eyes; *d*, posterior cords, supplying abdominal viscera.

The blood-vascular system consists of a dorsal contractile vessel, analogous to that found in Insects, but exhibiting an advance in structure on that of the latter group. From the heart, arterial trunks take their origin, these vessels distributing blood throughout the system, whilst the venous or impure blood appears to circulate through sinuses or spaces in the body, and thus to return to the respiratory organs for purification. After purification, the aërated blood is returned to the heart by another and distinct set of vessels.

The respiratory organs consist in typical Arachnidans of pulmonary sacs or lung-chambers, formed by an involution, or folding inwards, of the integument, and communicating with the external air by apertures situated usually on the lower surface of the body, and to which the term "stigmata" (Fig. 56, D, *s s*) is applied. The interior of each sac is occupied by a series of "lamellæ," or membranous plates, the flat surfaces of which are closely applied to each other, like the similar arrangement of leaves in a book. The minute capillary blood-vessels, carrying venous blood, ramify over the surface of each plate, a considerable area being thus formed for the exposure of the blood to the air, and for its due aëration. Tracheæ or air-tubes, constructed on the same typical plan as those of insects, may exist either separately or in combination with these pulmonary sacs; and in the lower forms respiration appears to be performed by the general surface of the body.

The nervous system, whilst usually exhibiting the typical character of a gangliated ventral chain, shows in certain forms, exemplified by the Spiders, a tendency towards the concentration and massing together of the nervous centres. In the Spiders, the nervous system is accordingly modified in disposition, and is found to consist of a large compound ganglion, situated on the floor of the cephalothorax (Fig. 56, E), and representing the typical ventral chain found in the Scorpions, and in other members of the group. Thus the cerebral ganglia are depicted at *c*, and from these lobes nerves arise to supply the eyes and other organs of sense. At *a* the principal mass is observed, this ganglion consisting of the united abdominal ganglia; and from this centre nerves (*d*) radiate to supply the adjacent abdominal viscera. The thoracic ganglia (*b b*) exist as fusiform bodies attached to the central mass; and from these latter the nervous supply of the limbs is derived. The eyes vary in number from two to eight, these organs in Arachnidans being exclusively of simple structure (ocelli). The sense of touch is supposed to reside, primarily, in the maxillary palpi, the great development of which, in the present instance, has been previously alluded to; but the extremities of the legs and general surface of the body are in all probability also endowed with sensibility. The sexes in Arachnidans, with the exception of the small division of the "Sloth" or "Bear-animalcules," are situated in distinct individuals. The young do not undergo a definite metamorphosis, but appear to moult, or cast their skins frequently, before attaining the mature and adult form.

CLASSIFICATION. — The nature of the respiratory organs has been used to divide the class into two primary sections, named respectively the *Trachearia* and *Pulmonaria*. In the *Trachearia*, respiration is performed either by means of air-tubes (tracheæ), the structure and disposition of which is essentially similar to that of insects; or by the general surface of the body. Among the *Pulmonaria*, as implied by this term, the respiratory organs exist in the form of pulmonary sacs, which may, however, be combined with tracheæ. A further distinction is found in the number of eyes, which, in the former division, never exceed four; whilst in the latter group they may number six or more.

SECTION I. TRACHEARIA.—Under the *Trachearia* are included the following four orders:—

Order 1. *Pantopoda* (*Pycnogonida*).—This order includes a few aberrant forms, the relations of which have not yet been definitely settled. From their aquatic habits they have been termed "Sea-spiders." The *Pycnogonum*, found as a parasite on Fishes (Fig. 57, *a*), is the most familiar example, whilst other members of the group live amongst the seaweed, and under the stones on the beach. The abdomen is rudimentary, and the legs are greatly developed.

Order 2. *Linguatulina* (*Pentastomida*).—The forms included in this division are of worm-like shape, and live parasitically in the lungs and other parts of mammals. The typical representative of the group is the *Linguatula* (or *Pentastoma*) *tænoides*, found in the frontal sinuses, or spaces in the frontal bone of the dog. The legs are represented by two anterior hooks.

Order 3. *Tardigrada* (*Arctisca*).—The "Sloth," or "Bear-animalcule" (*Macrobiotus*), found in the sand and refuse of the gutters of house-tops, typically exemplifies this group. The legs are rudimentary, and the circulatory and respiratory apparatus appear to be wanting in these creatures. They appear to possess wondrous powers of resuscitation, after existing in a dry and parched state for an indefinite period. The *Tardigrada* alone, of all Arachnidans, are hermaphrodite.

Order 4. *Acarina*.—The Mites and Ticks, representing this order, are for the most part of microscopic size, and exist principally as parasites on man and the higher animals. The abdomen does not exhibit an annulated or segmented appearance, and merges insensibly into the cephalothorax, the divisions of the body being thus indefinitely marked. The legs are usually well developed, the feet being in many instances furnished with terminal claws, whilst the body, generally, is covered with hairs, bristles, and other appendages. The mouth is suctorial, and in some cases is provided with a "rostrum" or "beak," for piercing the skin of the animal upon which the mite resides.

The Common Mite (*Acarus domesticus*, Fig. 57, *c*) is the most familiar example of the group, which, however, also contains other genera, interesting from a medical point of view, inasmuch as they are capable of producing a diseased condition in the individual upon whom they exist. Thus the *Sarcoptes scabiei*, or "Itch-mite" (Fig. 57, *d*), causes the disease familiarly termed itch; and another mite — *Demodex* — harmless in character, infests the follicles of the human skin, from which circumstance the specific name—*folliculorum*—is derived. The Ticks (*Ixodes*) (Fig. 57, *b*) infest many of the lower animals, and retain their hold upon the skin by means of the "rostrum" with which the mouth is provided. The dog and sheep, in particular, are liable to the attacks of these minute pests.

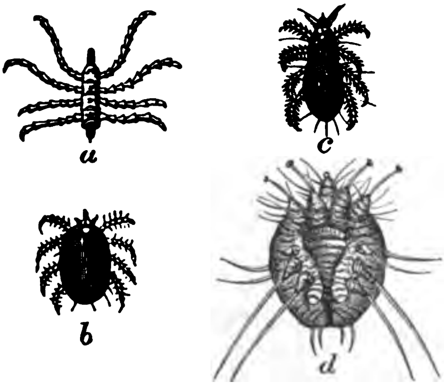


Fig. 57. TRACHEARIA.

a, *Pycnogonum littorale*, or "Sea-spider; *b*, *Ixodes plumbeus*, one of the "Ticks;" *c*, *Acarus domesticus*, the Domestic mite; *d*, *Sarcoptes scabiei*, the "Itch-mite."

SECTION II. PULMONARIA.—In this section are included the two remaining orders:—

Order 5. *Arthrogastra* (*Pedipalpi*).—The *Arthrogastra*, represented by the Scorpions (*Scorpionidæ*), (Fig. 58, *a*), and allied forms, exhibit, as implied by the technical name of the group, an annulated condition of the abdomen. The term *Pedipalpi*, sometimes applied to this group, is indicative of the enlarged maxillary palpi, which, in these creatures, constitute formidable prehensile organs (*chelæ*); the mandibles also being developed to form armed claws (*cheliceræ*). The extremity of the abdomen is furnished with a hooked fang, at the base of which a poison-gland is situated. The skin is hard and chitinous, an exoskeleton being thus formed. The "stigmata" (Fig. 56, D, *s*), to the number of eight, are placed on the ventral or abdominal surface of the first four abdominal segments, and communicate with eight pulmonary sacs, the typical structure of which has been already noticed.

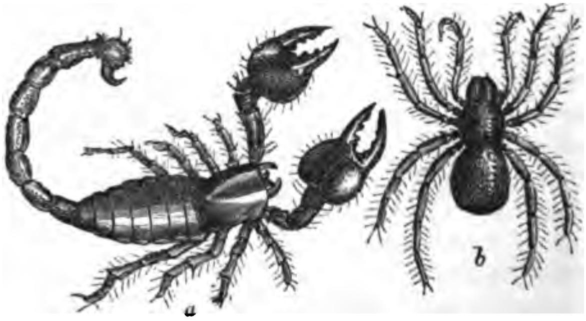


Fig. 58. PULMONARIA.

a, Scorpion (*Scorpio afer*), (reduced); *b*, Trap-door Spider (*Mygale cæmentaria*), (reduced).

Scorpions inhabit the warmer regions of the earth, and are justly dreaded on account of their sting, which is said to cause severe, if not dangerous symptoms.

Classified with the present group—but sometimes included as a distinct order with the *Trachearia*—the "Book-scorpions" (*Cheliferidæ*) are found. These creatures derive their name from the circumstance of their being found amongst old books, and closely resemble their more formidable neighbours in form and appearance. The "Harvest-spiders" (*Phalangidæ*), with several other typical genera, are by Huxley classified with the present group.

Order 6. *Araneina.*—The true Spiders, as representing this concluding order, are distinguished by their unsegmented abdomen, which is "connected with the cephalothorax by a narrow peduncle." The mandibles are terminated by simple hooks, and the maxillary palpi are modified in the males to subserve some part of the reproductive process; whilst in the females these organs are, like the mandibles, terminated by hooked processes. Respiration is performed by pulmonary sacs, in combination with tracheæ. The most distinctive and characteristic feature of the group, however, consists in the possession of a peculiar apparatus, by means of which the spiders construct a web or net for the capture of their prey. This apparatus consists of four peculiar teat-like organs, called "spinnerets" (Fig. 56, B, *a a*), and which are situated at the posterior extremity of the abdomen, together with two more elongated and filiform appendages (*b*), these latter being, in all probability, used to direct the movements of the thread in the weaving process. Each "spinneret" is pierced at its apex by an immense number of minute apertures, and through these apertures the silky fluid, secreted by special glands situated internally, and communicating with the "spinnerets," is pressed; this fluid becoming, on exposure to the air, of a tenacious consistence, so that it is capable of being drawn out in fine threads or strands. The many filaments furnished by a single "spinneret," unite to form the apparently single thread of each organ, whilst the compound threads thus furnished by the several "spinnerets" are, in turn, united to form the main and single filament used in the construction of the web. This final thread is therefore of a doubly compound nature, consisting, firstly, of the four threads furnished by the "spinnerets," each individual thread of a "spinneret" being, in turn, composed of very many finer strands. The feet, maxillary palpi, and filiform appendages of the spinnerets, appear to be the agencies by means of which the web is fixed and constructed.

The forms of the web, and the purposes to which it is applied, are very varied and interesting. The geometrical web of the common Garden-spider (*Epeira diadema*) is familiar to all; whilst the close fabric of the domestic species (*Tegenaria domestica*) also exhibits another variety in form and construction. The Mason-spiders (*Mygale*) (Fig. 58, *b*) excavate a nest or pit in the ground, which they line with the silk secretion, and the entrance to which is closed by an accurately-fitting lid, from which their familiar name of "Trap-door" Spiders is derived. The nets of foreign genera are of very strong construction, small birds being sometimes entangled in their meshes, whilst their gorgeous and brilliant hues equally attract the attention of the traveller.

The Water-spider (*Argyroneta*) lives at the bottom of pools, where it constructs a bell-shaped nest or habitation. It is a direct atmospheric breather, and frequently ascends to the surface of the water for this purpose, carrying with it in its descent a bubble of air, entangled in the hairs with which its body is covered, and with which it fills its subaqueous abode; returning in a short time to the surface for a fresh supply.

In the disposition of their nervous system, Spiders exhibit the massing together and coalescence of their nervous centres, before alluded to. And when we consider the tact and cunning exhibited by these creatures, and the artifices which they resort to in the construction of their net, the capture of prey, and the due storing of their food, we cannot feel surprised at this tendency to centralisation of the nervous centres, but, on the contrary, regard the increased specialisation as prepared to meet the demand for nervous power, adequate to the performance of these higher functions.

CHAPTER XIII.

ANNULOSA.—(*Continued.*)

ARTHROPODA. CLASS IV. CRUSTACEA.

General Characters of Crustacea—Classification—Orders of Crustacea.

THE three preceding classes of the Arthropoda are terrestrial in their habits; the *Crustacea*, constituting the fourth and highest division, differ from the other groups, in that they, for the most part, lead an aquatic life, breathing the air through the watery medium, by means of branchiæ or gills. The annulose or segmented character of the body is generally well marked. As in the *Arachnida*, the head and thorax are amalgamated to form a "cephalothorax," whilst locomotive appendages are borne by the abdominal, as well as by the thoracic segments: the locomotive appendages exceed eight in number, and two pairs of antennæ are present; these characters serving generally to distinguish the *Crustacea* from the other groups included in the Arthropodous section of the Annulosa. The *Crustacea* are represented by Crabs, Lobsters, Barnacles, Water-fleas, Wood-lice, and allied forms. Their bodies, in the typical members of the group at least, are protected by a hard calcareous exoskeleton, familiarly known as the "shell;" and this outer covering is wholly renewed at certain periods of the creature's existence, by being exuviated or cast off, a fresh deposition of calcareous matter in the soft integument giving rise to the formation of the new "shell." Of the numerous locomotive appendages borne by the segments of the body, those of the thorax are generally alone employed as true walking limbs; the abdominal appendages subserving various purposes, their most common use being to fasten and retain the ova at the time of fertilisation.

The digestive, blood-vascular, and nervous systems, retain, for the most part, the Annulose characteristics, the respiratory organs, as previously mentioned, being modified to suit the requirements of the aquatic habits of the class.

Classification.—The *Crustacea* are divided into eight orders:—

Order 1. *Cirripedia.* Ex. Barnacles (*Lepas*).
Order 2. *Entomostraca.* Ex. *Cyclops.*
Order 3. *Branchiopoda.* Ex. *Daphnia.*
Order 4. *Pœcilopoda.* Ex. King-crabs (*Limulus*).
Order 5. *Isopoda.* Ex. Wood-lice (*Oniscus*).
Order 6. *Amphipoda.* Ex. Sand-hoppers (*Talitrus*).
Order 7. *Stomapoda.* Ex. Locust-shrimps (*Squilla*).
Order 8. *Decapoda.* Ex. Lobsters (*Homarus*).

Order 1. *Cirripedia.*—The members of this group—epresented typically by Barnacles (*Lepadidæ*) and "Sea-corns" (*Balanidæ*)—are fixed, and attached in their adult condition, but are free and undergo a metamorphosis during their young and embryonic state. The Barnacle attaches itself to submarine or floating objects, by an elongated peduncle or stalk (Fig. 59, 1), at the free extremity of which the body of the animal, encased within a "multivalve" shell, is found. The shell is composed of five calcareous plates united by a membrane; and from between the anterior edges of the valves the "cirri," or tentacle-like filaments (Fig. 59, 1, 2), which represent the legs of other Crustaceans, protrude. These "cirri"—from the presence and relations of which the term *Cirripedia* is derived—are twelve in number, and act as prehensile organs, creating by their movements currents in the

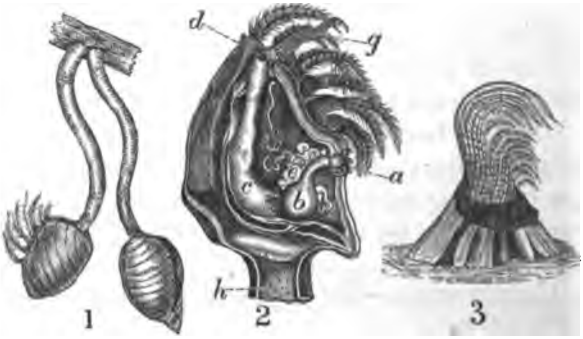


Fig. 59. CIRRIPEDIA.

1. Common Barnacles (*Lepas anatifera*). 2. Anatomy of Barnacle—*a*, mouth; *b*, stomach; *c*, intestine; *d*, anus; *e*, liver; *f*, reproductive apparatus; *g*, tubular organ connected with reproduction; *h*, muscular lining of peduncle or stalk. The six pairs of "cirri," representing the limbs of other Crustaceans, are also represented in the figure. 3. *Balanus*, or "Acorn-shell," with protruded cirri.

water, and thus drawing particles of nutrient matter towards the mouth (Fig. 59, 2, *a*), which is situated at the bases of the "cirri." A masticatory apparatus exists within the oral cavity, from which an œsophagus leads to a distinct stomach (*b*), surrounded by the voluminous folds of a large liver (*e*). The intestine (*c*) is continued in a straight course to the anus, which opens superiorly to the mouth. The circulatory apparatus is of the most rudimentary description; and the function of respiration appears to devolve upon certain tentacular appendages situated in the neighbourhood of the mouth, the "cirri," in all probability, also subserving the respiratory process.

The sexes are generally united in the same individual, the Cirripedia being thus hermaphrodite, although certain forms, termed "complementary males," appear from time to time to be developed, these latter forms attaching themselves to the ordinary Cirripedes, and aiding in fertilising the ova of these hermaphrodite individuals. The generative organs in *Lepas* are depicted at *f*, Fig. 59, 2; and at *g*, an elongated tubular organ, supposed to be intimately connected with the reproductive process, is also seen. The embryos, during the earlier stages of their existence, are free and unattached, and resemble closely in form the adults of other groups, more particularly those of the *Entomostraca*. They are provided with natatory or swimming appendages, by means of which they move actively through the water, the final stages in their development being marked by their attaching themselves to some fixed object, and by the subsequent growth of the peduncle or stalk, characteristic of the adult form.

The *Cirripedia* include two families, in the first of which the *Lepadidæ* (Fig. 59, 1)—the Barnacles—are contained. The *Balanidæ*, forming the second family, are represented by the *Balani* or "Sea-acorns," which differ from the Barnacles in that the animals are sessile, and unprovided with stalks, the shells being attached directly to the rocks or stones on which they exist. The shell of the *Balanus* (Fig. 59, 3) consists of a short conical structure, composed of six calcareous pieces; the superior aperture of the shell, through which the "cirri" are protruded, being protected by a curious valvular apparatus (operculum), which can be opened or closed at the will of the creature. The "cirri" are specially developed in the present instance, and, in the absence of any specialised respiratory apparatus, would appear to subserve the breathing function. The "Sea-acorns" are exceedingly common around all our coasts, studding thickly the rocks and stones at low-water mark.

Orders 2 and 3. *Entomostraca and Branchiopoda.* —These orders are closely related to each other, and include nearly-allied forms. The general term, "Water-fleas," has been applied to the representatives of these groups, these creatures inhabiting fresh-water ponds and lakes. They are generally of minute, often of microscopic, size, the most familiar examples being the *Cyclops* and *Daphnia*. The *Cyclops* (Fig. 60, *a*), so named from the large and single eye with which it is provided, is covered by a shelly "carapace" or shield, the presence of this latter investment constituting the characteristic feature of the *Entomostraca*, or "shelled insects." The head is distinctly marked, as also are the abdominal segments. The antennæ are largely developed, and appear to be used as natatory organs. The respiratory organs are but imperfectly developed in the *Entomostraca*. The reproductive organs are, however, highly specialised, these creatures possessing an amazing fecundity, and the young passing through a definite metamorphosis.

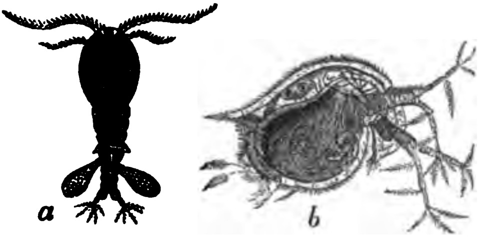


Fig. 60. ENTOMOSTRACA AND BRANCHIOPODA.

a, *Cyclops communis*, a common "Water-flea," showing posterior ovisacs, or egg-receptacles; *b*, *Daphnia pulex*, the "Branched-horned" Water-flea.

The *Branchiopoda* are typically represented by the *Daphnia* (Fig. 60, *b*), familiarly known as the "Branched-horned Water-flea." The respiratory organs exist in the form of fringed branchiæ attached to the thoracic appendages, the disposition of the breathing-apparatus giving rise to the technical name of the group. The antennæ are of large size, and are branched; these organs in all probability being used for swimming.

The females are of large size as compared with the males, which are also comparatively few in number; the entire process of reproduction and development in these creatures exhibiting many features of great interest.

The *Trilobita* represent a curious order of extinct Crustaceans, the fossil remains of which are characteristic of the *Palæozoic*, or most ancient of the life-periods of palæontologists. The *Calymene Blumenbachii*, depicted at Fig. 61, *a*, exemplifies one of the most typical of Trilobitic forms. These extinct Crustaceans possessed close relations with the preceding groups. The body was vertically divided into three lobes or divisions,—hence the name *Trilobita*,—and appears to have been covered with a hard exoskeleton. The eyes formed peculiar features in the organisation of these creatures, these organs exhibiting a compound structure, similar in character to that described in the

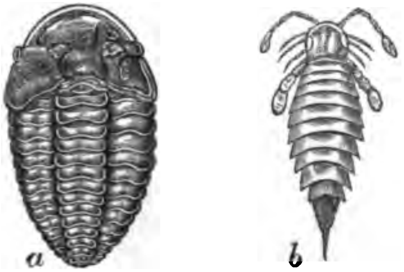


Fig. 61. TRILOBITA AND EURYPTERIDA.

a, *Calymene Blumenbachii*, a Trilobite, from the Silurian system; *b*, *Pterygotus Anglicus* (dorsal aspect), an example of the *Eurypterida*.

case of certain insects. From their frequent occurrence in Palæozoic formations, we infer that the Trilobites must have existed in immense multitudes in those ancient seas, and that they must have chiefly, if not solely, represented Crustacean life in the early life-period of which they are characteristic fossils.

Order 4. *Pœcilopoda* (*Merostomata*).—The *Limuli*, or "King-crabs" (Fig. 62), sometimes included in another group under the term *Xiphosura*, and inhabiting the islands of the Eastern Archipelago, are the sole representatives of this order, which, however, includes some fossil forms. The anterior segments of the body are united to form the convex "carapace" (Fig. 62, A, *a a*),

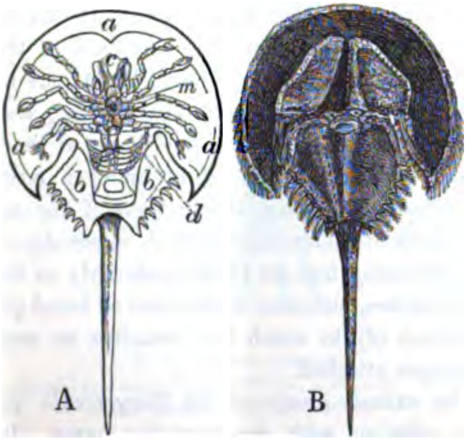


Fig. 62. Pœcilopoda.

A, Under-surface of "King-crab" (*Limulus polyphemus*); *a a a*, carapace *b b*, thorax; *c*, chelate antennæ; *d*, operculum, covering reproductive organs and branchial or breathing plates; *m*, mouth. B, Dorsal aspect of Limulus.

including the cephalothorax, and containing the various organs; whilst the posterior portion is elongated to form a terminal, sword-like, spinous tail (*telson*), from the presence of which the term *Xiphosura* or "sword-tailed" Crustaceans is derived. On the upper and convex surface of the "carapace," the eyes, which exist in the form of both simple and compound organs, are placed, whilst the concave, or under surface, bears the locomotive and other appendages. In the Limulus, thirteen pairs of appendages exist, and of these, six pairs, in the form of legs (Fig. 62, A), are attached round the margin of the oral aperture (*m*), the spines with which the basal or proximal joints of the legs are furnished, subserving the function of a masticatory apparatus. Anteriorly, and in front of the mouth, a pair of chelate antennæ (Fig. 62, A, *c*) are also situated. The remaining feet are placed posteriorly on the abdominal surface, and exist in the form of broad plate-like structures (*d*), to which the branchiæ or respiratory organs are attached.

The extinct group of the *Eurypterida* possessed close relations with the preceding forms. In these fossil genera, however, the head alone appears to have been provided with distinct appendages. The two genera, *Pterygotus* and *Eurypterus*, are included in this group, the most familiar form, that of the *Pterygotus Anglicus*, being depicted at Fig. 61, *b*. Like the *Trilobites*, the *Eurypterida* are solely characteristic of the *Palæozoic* life-period.

Order 5. *Isopoda* (*Edriophthalmia*). Of this group the *Oniscus*, or Wood-louse (Fig. 63, A), may be selected as embodying its characteristic features. The body is of oval shape, and distinctly segmented, the head, bearing sessile eyes, being easily recognisable. The seven thoracic segments bear each a pair of limbs, whilst the respiratory organs, in the form of fringed branchiæ, are attached to the under surface of the abdominal somites.

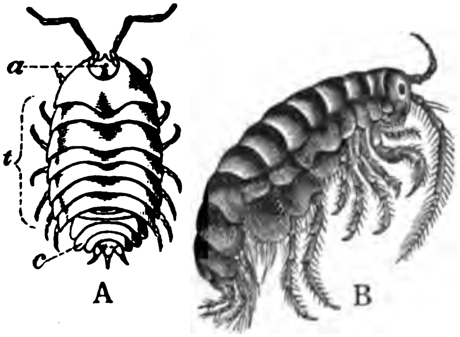


Fig. 63. Isopoda and Amphipoda.
A, Wood-louse (*Oniscus*); *a*, head ; *t*, thorax ; *c*, abdomen. B, *Talitrus locusta*, the Common Sandhopper (enlarged).

The *Oniscidæ* inhabit damp situations, such as underground cellars, among leaves, and under stones. When alarmed they roll their bodies up into a round ball, presenting a smooth chitinous surface, which thus serves for a covering and defence.

The *Isopoda*, with the succeeding division of the *Amphipoda*, are by some authorities grouped under a common order, to which the name of *Edriophthalmia*, or "sessile-eyed" Crustaceans, is applied, in contradistinction to the *Podophthalmia* or "stalk-eyed" Crustacea, —the latter division embracing the two remaining orders of the *Stomapoda* and *Decapoda*.

Order 6. *Amphipoda.*—The members of this group closely resemble the *Isopoda*, but differ from the latter forms, in that the respiratory organs are attached to the thoracic appendages, the branchiæ of the *Isopoda* being borne on the abdominal segments. The *Talitrus* or Sandhopper (Fig. 63, B), and the *Gammarus* or Fresh-water Shrimp, represent the present order. The head is distinct from the thoracic segments, bears sessile eyes, and is provided with two pairs of antennæ.

The Sandhoppers exist in myriads on every sandy beach, and are remarkable for their extreme agility, the limbs being especially developed, and enabling these creatures to execute considerable leaps. The *Gammarus* closely resembles in size and form its marine neighbour, the *Talitrus*.

Order 7. *Stomapoda.*—This group, which, with the succeeding order, is included in the general term *Podophthalmia*—includes a few forms, of which the most typical is the *Squilla* or Locust-shrimp. The legs number six or eight pairs, and the branchiæ are usually suspended from the abdominal segments; or these organs may, in certain cases, be attached to the thoracic somites. A characteristic and distinctive feature is formed by the stalked compound eyes. The *Squilla* resembles, in many points of structure, the ordinary *Decapodous* Shrimps, from which, however, it is to be carefully distinguished.

Order 8. *Decapoda.*—The last and highest order of the *Crustacea* includes Lobsters, Shrimps, and the various kinds of Crabs. The development of the calcareous exoskeleton is carried to its greatest extent in this order, the whole body, including the limbs, being encased in a hard shelly covering. The head and thorax, consisting, each, of seven segments—as in the Lobster, which may be selected as a typical example of the group—are massed together in a cephalothorax (Fig. 64, 1), which is covered dorsally by a firm shield or "carapace," and terminates anteriorly in a pointed process, to which the term "rostrum" or "beak" is applied. The abdominal segments, seven in number, and constituting the "tail" of the lobster, are articulated to and move freely upon each other. Every segment of the body is provided with appendages, which, however modified or altered throughout the body, are easily referred to the same type or plan of structure; the segments and appendages, in this respect, forming a typical example of "serial homology."

Selecting an abdominal segment—the third somite exhibiting the typical structure to greatest advantage—for examination, we find the segment to be composed of a body and appendages. The body consists of a convex upper portion, to which the name of "tergum" (Fig. 64, 5, *t*) is applied, and a slightly concave lower portion, termed the "sternum" (*s*); the lateral line of junction between these plates being prolonged downwards to form two side-plates termed "pleura" (*pp*). The appendages are two in number, and certain terminal parts are to be noticed in connection with each. These appendages, known as "swimmerets," consist each of a basal or proximal joint, articulated to the sternum, and termed the "protopodite," or "propodite,"

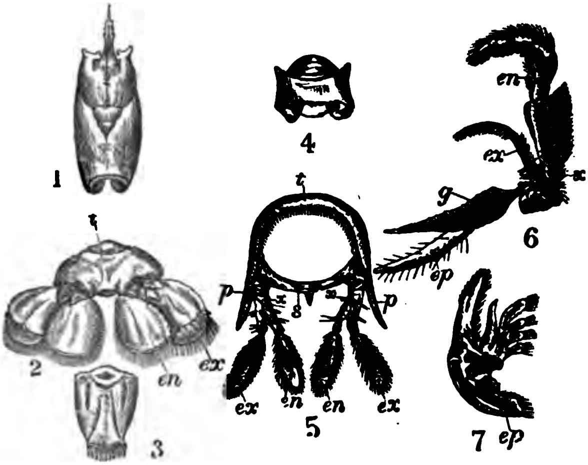


Fig. 64. Morphology of Lobster.

1. Carapace of lobster (cephalothorax). 2. Sixth abdominal segment and its appendages, viewed from above; *t*, tergum; *ex*, exopodite; *en*, endopodite. 3. Last abdominal segment (telson) detached from its normal position on the sixth segment (2). 4. Third abdominal segment from above. 5. Third abdominal segment in profile, showiug its structure and appendages; *t*, tergum; *s*, sternum; *p p*, pleura; *x*, propodite; *ex*, exopodite; *en*, endopodite. 6. One of the third pair of maxillipedes or "foot-jaws" (the letters refer to corresponding parts in Fig. 5); *g*, gill; *ep*, epipodite. 7. One of the second pair of maxillæ; *ep*, epipodite, known as the "scaphognathite."

(*x*, *x*); whilst this latter bears in turn two distal or terminal portions, known from their position respectively as the "exopodite," or outer appendage (*ex*), and "endopodite," or inner appendage (*en*). So far as the other abdominal segments are concerned, there is no difficulty in at once referring them to the same plan of structure as that described in the case of the third segment. The appendages of the first abdominal segment are but slightly modified in structure, the appendages of this somite being hard and calcareous in the male animal (Fig. 65, *r*). The second, third, fourth, and fifth, present no variations from the typical plan, but in the sixth segment (Fig. 64, 2) the appendages are found to undergo a marked development, and to deviate, in form at least, from those of the preceding joints. The "protopodite" (Fig. 64, 2) of the sixth segment is enlarged, and gives attachment to the "exopodite" (*ex*), and "endopodite" (*en*), both of which form broad expanded plates, contrasting forcibly with their more slender prototypes of the other segments; this modified apparatus constituting, with the last segment of all, the "tail-fin" of the Lobster. This seventh and last segment of the abdomen (Fig. 64, 3) is still further modified, and exists simply as a slightly conical plate attached to the sixth segment; it is destitute of appendages, and termed the "telson." The morphological relations of this seventh somite are by no means satisfactorily determined, some authorities considering it a true segment destitute of appendages, whilst others regard it in the light of a solitary and modified appendage.

The determination of the homologies of the thoracic and head segments is by no means difficult, a close examination of the various elements entering into the composition of these regions revealing the same typical structure. The thoracic segments bear the true locomotive limbs, the "protopodite" and "endopodite" being represented in the legs, and the "exopodite" being undeveloped. These limbs are ten in number, and are borne by five corresponding thoracic somites; the two remaining and anterior segments of this region bearing "maxillipedes" or "foot-jaws" (Fig. 64, *b*), which latter are merely modified limbs. The last segment of the head also bears a pair of "maxillipedes;" the homology of the "foot-jaws" with the abdominal appendages being clearly traceable. The six remaining segments of the head bear the other and true masticatory organs, the two pairs of antennæ (Fig. 65, *a*, *b*), and the pedunculated eyes, the stalks of these latter organs corresponding to the typical "protopodites."

The digestive system exhibits a high degree of specialisation, the mouth being furnished with three pairs of true jaws, in addition to the "maxillipedes" previously alluded to. As in Insects, an upper lip or "labrum," and an under lip or "labium," exist; a pair of mandibles, and two pairs of maxillæ, constituting the masticating apparatus. The second pair of maxillæ (Fig. 64, 7), whilst exhibiting the typical structure previously mentioned, bears in addition a membranous flap or appendage, termed the "scaphognathite" (Fig. 64, 7, *ep*), the office of which is to aid in the expulsion of the effete water from the respiratory chamber. Homologically viewed, the "scaphognathite" is known as the "epipodite" (Fig. 64, 6 and 7); this appendage being borne by the "protopodite," and being also present in the thoracic or locomotive limbs, save the last pair, and in the foot-jaws and maxillæ. The "epipodites" of the thoracic limbs project upwards and between the gills, these latter organs being attached to the bases of the legs (Fig. 64, 6, *g*). The œsophagus is short, and terminates in an oval stomach (Fig. 65, *s*), at the posterior extremity of which three strong calcareous teeth are situated. These organs are set in action by an appropriate muscular arrangement, which is under the control of the creature's will. The office of this apparatus is undoubtedly to assist the digestive process by further triturating and dividing the heterogeneous substances upon which these creatures feed. The intestine (*f*) is continued in a straight course to the anal opening (*h*), which is situated at the base of the "telson." A capacious liver (*o*) exists, and certain

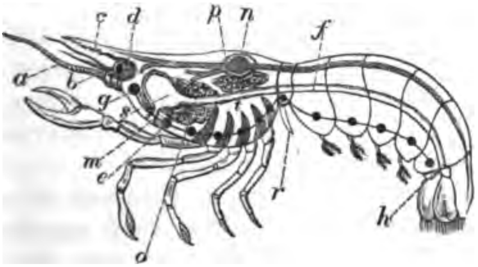


Fig. 65. Diagram of Lobster.

a, First pair of antennæ; *b*, second pair of antennæ; *c*, rostrum; *d*, eye; *e*, infra-œsophageal ganglion; *f*, intestine; *g*, supra-œsophageal ganglion; *h*, anus; *m*, mouth; *n*, heart; *o*, liver; *p*, generative organs; *r*, appendages of first abdominal segment, which in the male are of horny consistence; *s*, stomach; *t*, placed above branchiæ or gills.

glands, situated in the neighbourhood of the œsophagus, are supposed to be analogous with the salivary glands of higher forms.

The blood-vascular system consists of a dorsal contractile vessel (Fig. 65, *n*), from which arterial trunks arise to distribute the blood throughout the system. Having become venous in character, the blood is conveyed to the respiratory organs by venous channels or "sinuses," which exist between the tissues and organs, and which terminate in dilatations at the bases of the gills. From these the blood passes into the "branchiæ" (*t*), and, after aëration, is returned to the heart for re-circulation, by appropriate sinuses; these latter terminating in a larger sinus, which communicates directly with the heart by a series of valvular apertures.

The respiratory organs exist in the form of conical "branchiæ" or gills (*t*), each of which consists of a main trunk or stem, upon which numerous closely-set vascular láminæ or plates are supported. The gills are attached to the basal joints of the ambulatory limbs, and are contained in special cavities or chambers, situated under the "carapace," and on the sides of the thoracic region. Water is admitted to each branchial chamber by a posterior aperture, and expelled by an anterior aperture, situated near the oral opening. The efferent aperture is guarded by the "scaphognathite," which, by its movements, tends to sweep out the effete water, and, at the same time, to cause a fresh inflow from behind. A series of stiff membranous processes, termed "flabella"—formed by the "epipodites," of four pairs of thoracic legs—and which extend upwards between the gills, also aid, by the movements of the legs, in the expulsion of the effete water.

The nervous system presents the normal and typical Annulose characteristics, consisting of a gangliated ventral chain (Fig. 65), liable, however, to occasional modifications in form and disposition throughout the group. The ganglia in the neighbourhood of the head and œsophagus, from their position, rank highest in the consideration of the nervous centres. Thus the nervous mass at *g*, Fig. 65, situated above the œsophagus, is accordingly termed the "supra-œsophageal" or "cephalic" ganglion, whilst that at *e*, placed below the gullet, is known as the "infra-œsophageal" ganglion.

Organs of sense are specially developed in the *Decapoda*, the eyes being of the compound variety, whilst the auditory or hearing sense appears to reside in two auditory vesicles situated at the basal joints of the second pair of antennæ. Two pairs of antennæ exist, a larger pair (Fig. 65, *a*), and a smaller pair, termed "antennules" (*b*). In these latter organs the "protopodite" is represented by the common basal joint in each organ, the "endopodite" and "exopodite" being developed, but more especially and typically in the latter pair.

The sexes exist in different individuals, the ova being carried about by the female, and supported on the abdominal "swimmerets." In certain members of this group, represented by the Crabs, the young pass through a metamorphosis before attaining the mature form; the young animals in their successive stages, until of late years, having been described as distinct and independent forms, under the respective names of *Zoea* and *Megalopa*, (Fig. 66, *a b c*).

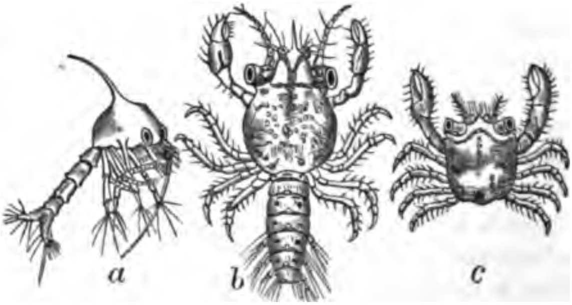


Fig. 66. Metamorphosis of Crab.
a, Embryonic form of crab, known as *Zoea pelagica*; *b*, more advanced stage of *a* (*Megalopa*); *c*, advanced stage of *b*.

Classification.—The *Decapoda* are divided into three natural groups, distinguished by the form and arrangement of the abdominal or tail-segments.

In the first of these groups—that of the *Macrura* or "Long-tailed" Decapods—the abdominal segments are well developed, forming a distinct tail. The Lobsters and Cray-fish (*Astacidæ*), Shrimps, and Prawns (*Crangonidæ*), represent this division.

The *Anomura* or "Irregular-tails" are represented by the *Paguridæ* or "Hermit-crabs," found around our coasts, ensconced in the cast-off shells of Whelks and other Molluscs. Of this group the Common "Hermit"-crab (Fig. 67) may be selected as a typical example. The abdomen is soft, and unprotected by any calcareous exoskeleton, and hence the reason that the creature seeks refuge in the shell. The extremity of the abdomen is furnished with rudimentary feet, forming a sucker-like apparatus, by means of which the Hermit-crab is enabled to retain a firm hold of the whorls of his habitation. One of the larger "chelæ" or claws is developed to a much greater extent than the other, this enlarged member serving to close the aperture of the shell, when the Crab has withdrawn into its abode.

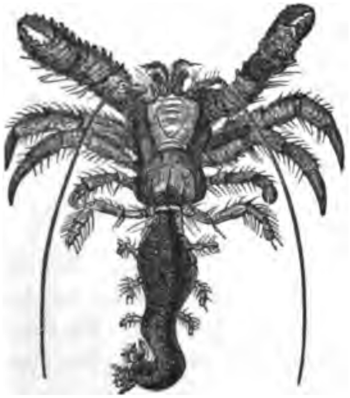


Fig. 67. ANOMURA.

Pagurus Bernhardus, the Common "Hermit" or "Soldier" crab.

The *Brachyura* or "Short-tails," represented by the various kinds of Crabs, are distinguished by the rudimentary or abortive nature of the abdomen, this circumstance giving rise to the technical name of the group. The body (cephalothorax) is extended laterally, the abdomen forming a mere shortened appendage, which rests on the front of the cephalothoracic wall. The Common Crabs (*Canceridæ*), Spider-crabs (*Maiadæ*), and the Land-crabs (*Gecarcinidæ*), of tropical climates, exemplify the most familiar members of the group, which, however, includes a large number of species.

CLASSIFICATION OF ANNULOSA.

SECTION A. ANARTHROPODA.

CLASS I. GEPHYREA. Ex. Sipunculus.
CLASS II. ANNELIDA.
- Order (a) *Hirudinea.* Ex. Hirudo.
- Order (b) *Oligochæta.* Ex. Lumbricus.
- Order (c) *Tubicola.* Ex. Serpula.
- Order (d) *Errantia.* Ex. Nereis.

SECTION B. ARTHROPODA.

CLASS I. MYRIAPODA.
- Order (a) *Chilopoda.* Ex. Scolopendra.
- Order (b) *Chilognatha.* Ex. Iulus.

CLASS II. INSECTA.
- DIVISION 1. AMETABOLA.
  - Order (a) *Anoplura.* Ex. Pediculus.
  - Order (b) *Mallophaga.* Ex. Philopterus.
  - Order (c) *Thysanura.* Ex. Podura.
- DIVISION 2. HEMIMETABOLA.
  - Order (d) *Hemiptera.* Ex. Notonecta.
  - Order (e) *Orthoptera.* Ex. Locusta.
  - Order (f) *Neuroptera.* Ex. Libellula.

Division 3. Holometabola.
- Order (g) *Aphaniptera.* Ex. Pulex.
- Order (h) *Diptera.* Ex. Musca.
- Order (i) *Lepidoptera.* Ex. Papilio.
- Order (j) *Hymenoptera.* Ex. Apis.
- Order (k) *Strepsiptera.* Ex. Stylops.
- Order (l) *Coleoptera.* Ex. Carabus.

Class III. Arachnida.

Division 1. Trachearia.
- Order (a) *Pantopoda.* Ex. Pycnogonum.
- Order (b) *Linguatulina.* Ex. Linguatula.
- Order (c) *Tardigrada.* Ex. Macrobiotus.
- Order (d) *Acarina.* Ex. Acarus.

Division 2. Pulmonaria.
- Order (e) *Arthrogastra.* Ex. Scorpio.
- Order (f) *Araneina.* Ex. Tegenaria.

Class IV. Crustacea.
- Order (a) *Cirripedia.* Ex. Lepas.
- Order (b) *Entomostraca.* Ex. Cyclops.
- Order (c) *Branchiopoda.* Ex. Daphnia.
- Order (d) *Pœcilopoda.* Ex. Limulus.
- Order (e) *Isopoda.* Ex. Oniscus.
- Order (f) *Amphipoda.* Ex. Talitrus.
- Order (g) *Stomapoda.* Ex. Squilla.
- Order (h) *Decapoda.* Ex. Homarus.

CHAPTER XIV.

MOLLUSCA.

General Characters of Mollusca—Classification—Polyzoa—Tunicata—Brachiopoda.

THE term *Mollusca*, derived from the Latin *mollis*, *soft*, expresses a general characteristic of the sub-kingdom. In the majority of instances, however, we find the soft bodies of the Mollusca protected by a hard calcareous exoskeleton, familiarly known as the "shell," and which is secreted by a peculiar membrane, to which the term "pallium" or "mantle" is applied. The digestive system exhibits a high degree of specialisation; salivary glands, a capacious liver, and a renal or urinary system, being very generally represented throughout the group. The circulatory system in the higher forms consists of a distinct two-chambered heart; one cavity —the auricle—being devoted to the reception of purified blood from the respiratory organs; the other cavity —ventricle—propelling it through the system. The respiratory apparatus is represented in the lower forms by ciliated tentacles or branchial sacs; whilst in the higher divisions of the sub-kingdom, true gills or "branchiæ," and "pulmonary" or lung-sacs, are found, according as the respiration is aquatic or aërial. The character and disposition of the nervous system, however, furnish the most characteristic peculiarity of structure in the consideration of the Molluscan type. Typically, the nervous system of the Mollusca consists of three principal nervous masses or "ganglia" (Fig. 78), connected together by bands or "commissures" of nerve-matter. Of these, the first and most important in function and relations is situated above the œsophagus or gullet; this first great centre being accordingly termed the "supra-œsophageal" ganglion, whilst its analogy with the brain of higher animals procures for it the synonymous name of "cerebral" ganglion. The second centre is situated inferiorly, being found in the neighbourhood of the "foot" or locomotive disc, and to this latter the term "pedal" or "infra-œsophageal" ganglion is applied. The third mass is placed superiorly, and, from its contiguity to the breathing organs, has been named the "branchial" ganglion; or, from the fact of its supplying with nervous filaments the walls of the body and the viscera generally, the "branchial" ganglion is sometimes known as the "parieto-splanchnic" mass. This unsymmetrical disposition of the nervous system has given origin to the name *Heterogangliata*, a term used by Professor Owen as synonymous with Mollusca, and employed in contradistinction to the term *Homogangliata*, which, as previously noticed, is applied to the Annulosa, in reference to the regular disposition of the nervous system in that type of structure.

The Mollusca, however, do not exhibit a uniformity in the character of their nervous system, but, on the contrary, present so marked a modification of the typical plan, that, from this variation in the nervous axis the sub-kingdom has been divided into two primary groups or sections. In the first and lower group—that of the *Molluscoida*—the nervous system is represented by a "single ganglion, or, at most, by a principal pair, with accessory ganglia," situated in the neighbourhood of the œsophagus, or of the oral aperture. The *Mollusca Proper*, constituting the second and higher section, are characterised by the possession of a more perfect nervous system, constructed after the type already described. In addition to this principal difference between these two sections, a minor point of distinction is found in the degree of perfection to which the circulatory apparatus attains in the respective groups. Thus, in the *Molluscoida*, the circulatory system is of a very rudimentary description, or may be altogether unrepresented; whilst in the *Mollusca Proper* a distinct two-chambered heart exists.

The *Mollusca* are represented by the forms ordinarily known as "Shell-fish;" by "Cuttle-fishes;" by the "Sea-squirts;" "Sea-mats;" and other less familiar forms.

CLASSIFICATION.—The *Mollusca* are thus primarily divided into two sections:—

SECTION A. MOLLUSCOIDA.

CLASS I. *Polyzoa.* Ex. Sea-mats (*Flustra*).
CLASS II. *Tunicata.* Ex. Sea-squirts (*Ascidia*).

CLASS III. *Brachiopoda.* Ex. Lamp-shells (*Terebratula*).

SECTION B. MOLLUSCA PROPER.

CLASS IV. *Lamellibranchiata.* Ex. Oyster (*Ostrœa*).
CLASS V. *Gasteropoda.* Ex. Whelk (*Buccinum*).
CLASS VI. *Pteropoda.* Ex. Cleodora.
CLASS VII. *Cephalopoda.* Ex. Cuttlefish (*Sepia*).

SECTION A. MOLLUSCOIDA.

The *Molluscoida* are defined by Allman, as possessing "a central nervous system, consisting of a single ganglion, or of a principal pair, with accessory ganglia. Heart very imperfect, consisting of a simple open tube, or may be entirely absent."

CLASS I. POLYZOA.—As implied by the name *Polyzoa*, the animals included in this division form compound organisms, and in this respect bear some resemblance to, and possess certain analogies with, the Hydroid polypes, with which forms, indeed, they were long classified. The "Sea-mats" (*Flustrœ*), (Fig. 68, A), found attached to fixed objects, and so frequently mistaken for sea-weed, may be regarded as typical representatives of the group. The plant-like form of the Flustra is at once observable, but on more minute and careful examination, the entire structure, or "polyzoarium," is seen to consist of an aggregation of small cells (Fig. 68, B, C), bound together by a common integument, or "cœnœcium." Unlike the Hydroid polypites, however, there is no organic connection between the "polypides" or individual zooids of the Polyzoa; each "polypide" leading, in a manner, a separate and independent existence.

Selecting a single cell for examination, we find the

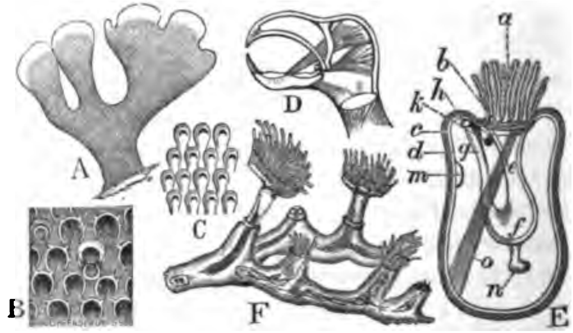


Fig. 68. Morphology of Polyzoa.

A, [Portion of Cœnœcium of *Flustra foliacea*, one of the "Sea-mats;" (natural size). B, A few cells of A, greatly magnified (Gosse). C, Small portion of *Flustra* (*Carbasea*) *papyrea* (magnified), showing the cells. D, One of the "Avicularia" or "Bird's-head processes" of Polyzoa (magnified), showing the muscular system. E, Diagrammatic section of Polyzoon (after Allman); *a*, ciliated tentacles; *b*, lophophore; *c*, ectocyst; *d*, endocyst; *e*, gullet; *f*, stomach; *g*, intestine, with neural flexure, terminating in the anus, *h*; *k*, nervous ganglion; *m*, ovary; *n*, testis; *o*, retractor-muscle. F, *Plumatella repens* (magnified), a fresh-water Polyzoon (Allman).

external integument, and that which is common to all the polypides, to consist of an outer, coriaceous, or leathery membrane, termed the "ectocyst" (Fig. 68, E, *c*), in which calcareous particles may be developed; whilst the interior of the cell is lined by a soft vascular membrane, provided with cilia, and to which the name of "endocyst" (*d*) is applied. The relation of these terms with the "ectoderm" and "endoderm" of the Cœlenterata will be readily recognised.

Situated at the superior extremity of the cell, the mouth, surrounded by a circle of ciliated tentacles, (Fig. 68, E, *a*) is found. The tentacles are borne on a disc or stage named the "lophophore" (*b*), the form of this organ, and the subsequent arrangement of the tentacles, consitituting the basis of the classification of this group. In the marine Polyzoa, the "lophophore" is simply circular in form, whilst in the fresh-water forms (Fig. 68, F) it assumes a crescentic or horse-shoe shape, this latter modification inducing a corresponding and characteristic arrangement of the tentacles. A special feature in the organisation of the Polyzoa consists in the power by which the upper part of the alimentary canal can be protruded from the cell (evagination), and again retracted within it (invagination.) Thus the lophophore and tentacles can be fully protruded from the oral aperture, or, on the other hand, retracted within it. To this end, a special muscular apparatus is developed in the Polyzoa, the retractor muscles (Fig. 68, E, *o*), by means of which the tentacles are withdrawn and invagination effected, being the most highly developed part of the system. The function of the tentacles is twofold; these organs being used, firstly, for the purpose of creating currents in the surrounding water, and thus drawing particles of nutrient matter towards the mouth; and, secondly, for the purpose of respiration;

the presence of cilia, with which they are furnished, rendering this idea the more probable.

Some species of Polyzoa, in addition to the tentacles, are provided with peculiar processes termed "avicularia," or "Bird's-head processes," one of which is figured at D, Fig. 68. These are situated externally on the ectocyst, and each consists essentially of an upper movable beak-shaped mandible, which is received into a lower cup-shaped portion. The mandible, by the action of appropriate muscles depicted in the figure, is seen to be constantly in motion. These singular organisms do not appear to possess any organic connection with the polypides, their movements continuing for a considerable period after the Polyzoon on which they reside has ceased to exist. Their function, like their relations, is quite undetermined, but it has been thought that they may serve to attract and secure passing objects of comparatively large bulk, around which smaller organisms may congregate, and thus be brought within reach of the currents excited by the ciliated tentacles. In their relations a considerable affinity to the "pedicellaria" of the Echinozoa will readily be perceived. In certain species a single, vibratile, lash-like filament, termed the "vibraculum," takes the place of the "avicularia."

A short gullet (E, *e*) leads from the mouth to a dilated stomach (*f*), from which an intestine (*g*) curves upwards and upon the first part of the alimentary canal, to terminate in a distinct anus (*h*), situated in close proximity to the oral aperture. Situated between the mouth and anus, and at the side of the œsophagus, the typical single nervous ganglion (*k*) is found; and as the intestine turns round towards the side of the body in which the nervous ganglion is situated, the intestinal flexure is accordingly said to be "neural." The relations of the nervous and alimentary systems thus expressed, is used by Huxley as a distinctive feature in the classification and general relations of the various groups into which the Mollusca are divided. The existence of a compound or "colonial" nervous system (Müller), extending through and connecting together the various "polypides," appears to be sufficiently determined to warrant its mention in the present instance.

No specialised circulatory apparatus exists in the Polyzoa, but the interior of the cell is filled with a clear fluid (perivisceral fluid), in which the viscera are suspended, and through which a circulation is, by aid of the ciliated endocyst, maintained.

The reproductive system consists of ovary (*m*) and testis (*n*), developed in one and the same individual, the Polyzoa being thus hermaphrodite. The ovary is situated superiorly, the testis occupying an inferior position, and being attached by a cord, termed the "funiculus," to the lower portion of the stomach. The power of "gemmation," so characteristic a feature of the Hydrozoa, is also to be noticed in the present instance, the Polyzoa also producing compound organisms by a process of "budding;" and a third form of the reproductive process exists, whereby certain peculiar bodies, termed "statoblasts," are produced within the cells of the polypides, these bodies, after liberation, giving rise by gemmation to forms resembling those from which they sprung.

The Polyzoa are divided into two orders, distinguished by the form of the "lophophore," and the presence or absence of a process overhanging the mouth, and termed the "epistome."

The first order, that of the *Phylactolæmata*, possess a bilateral, crescentic, or horse-shoe shaped lophophore, and an "epistome" is present. The term *Hippocrepia* has been used as synonymous with *Phylactolæmata*, the former name having particular reference to the "horse-shoe" shape of the lophophore. The forms included in this order, with one exception, inhabit fresh water, and of these the *Plumatella repens*, (Fig. 68, F), and the well-known *Cristatella*, may be cited as familiar examples. The *Cristatella*, though a compound organism, is endowed with a certain degree of locomotive power, the organism crawling by a muscular, ventral, flattened disc, or foot, resembling the similar organ in a snail. The "ectocyst" is absent in *Cristatella*.

The second order—*Gymnolæmata*—is distinguished by the orbicular or circular shape of the lophophore, and by the absence of an "epistome." The species included in this group, with a single exception, are all marine. The various species of *Flustræ* (Fig. 68, A, B, C), popularly known as "Sea-mats," constitute typical and familiar examples of this order, which is sometimes known as the *Infundibulata*, or "funnel-shaped," in allusion to the arrangement of the tentacles, and in contradistinction to the term *Hippocrepia*.

CLASS II. TUNICATA.—The "Tunicate" molluscs are broadly characterised by the investing "tunic" in which their bodies are enclosed.

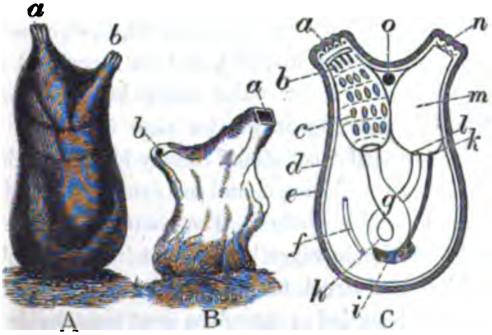


Fig. 69. MORPHOLOGY OF TUNICATA.

A, *Ascidia virginea*, one of the "Sea-squirts:" *a*, branchial or oral orifice; *b*, anal or atrial aperture. B, *Cynthia quadrangularis*: *a*, branchial aperture; *b*, atrial aperture. C, Diagrammatic section of Tunicate (after Allman): *a*, oral or branchial aperture; *b*, tentacles; *c*, branchial sac; *d*, outer layer or "test;" *e*, inner layer or "mantle;" *f*, heart; *g*, stomach; *h*, intestine; *i*, generative organs; *k*, efferent duct of generative system; *l*, anus, opening into "atrial" chamber, *m*; *n*, "atrial" aperture; *o*, nervous ganglion.

The *Ascidia*, or "Sea-squirts" (Fig. 69, A, B), found at low-water mark, adhering to stones and fixed objects, are familiar examples of this class. The form of these creatures has suggested their scientific name, their shape resembling that of the wine-bag or wine-skin of Eastern nations; or more familiarly that of a double-necked jar; whilst the familiar designation "Sea-squirts" has been applied to these forms, in allusion to their habit of emitting jets of water from the apertures when alarmed or disturbed.

The "tunic" of an Ascidian—which may be selected for examination, as embodying the chief structural peculiarities of the group—consists of two layers, an outer or external—the "test"—(Fig. 69, C, *d*), consisting of horny or leathery material, and an inner and more delicate vascular layer. The outer layer is mainly remarkable for being in greater part composed of a substance termed "cellulose," nearly identical, chemically speaking, with starch, and long considered to be an exclusive vegetable product. The discovery of the existence of an intimate vegetable product in close combination with animal structures, was, to use the words of Huxley, "justly regarded as one of the most remarkable facts of comparative physiology." The inner and more delicate layer (*e*), to which the term "mantle" has been applied, consists in greater part of muscular fibres, by the contraction of which the *Ascidia* is enabled to eject water from the orifices previously mentioned.

The superior extremity of the test bears two projections or necks (Fig. 69, A, B, *a a*, *b b*), on the summit of each of which an aperture, varying in form, is found. The first of these represents the mouth, whilst the second is known as the "anal," or "atrial" aperture. The oral opening (Fig. 69, C, *a*), in most cases provided with a circle of tentacles (*b*), which, however, differ from those of the Polyzoa, in being non-retractile, leads into a large dilated chamber, termed the "pharynx," "branchial," or "respiratory sac" (*c*); and which, as its name implies, subserves the function of respiration. The walls of this chamber present a reticulated or network structure, the edges of the quadrangular meshes being fringed with vibratile cilia. A minute examination of the walls of this dilated sac further shows that the dividing partitions or bars of the network are in reality hollow tubes or vessels, the function of which is clearly to circulate the blood throughout the organ, and thus to provide for its due aëration by exposure to the contained water. The mouth opens on the inferior aspect of this sac; but here it may be well to state that the scientific world is not well agreed as to which aperture is rightly to be regarded as the mouth. If we hold, with Huxley, that the "branchial" sac represents a greatly dilated and modified pharynx, then the outer and superior aperture of the body will fall to be considered as corresponding to the mouth of other animals; but if, on the contrary, we espouse the views of Professor Allman and others, who regard the "branchial" sac as homologous with the tentacles of the Polyzoa, then the lower and inferior opening of the sac will constitute the true oral aperture. The homology of this peculiar sac is thus so far undetermined, and it is well to bear in mind the particular relations which have thus been assigned to it. From the lower opening in the "branchial" sac a gullet is continued, and this dilates into a stomach (*g*), from which an intestine (*h*) is given off; this latter terminating, after a few convolutions, in a second sac, to which the names of "atrial chamber" or "cloaca" (*m*), have been applied. The "atrial" sac communicates with the exterior by the second of the two external apertures of the body; the term "atrial" aperture (*n*) being applied to this particular opening. The "branchial" or "respiratory" sac (*c*) is in free communication with the "atrial" chamber; but the relations of the two sacs, like those of the oral aperture and pharynx, are by no means satisfactorily determined. By some authorities, the branchial sac is believed to be contained within the atrial chamber; whilst other observers think that the lining membrane of the "cloaca" is reflected over the pharynx, and that the two sacs communicate, though in a less perfect manner than the former opinion would tend to show. At any rate, the cardinal fact of these sacs communicating freely with each other must be clearly borne in mind, as also that the clefts or meshes of the "branchial" sac, and the vibratile cilia with which these latter are fringed, aid in rendering this communication, in its functional aspect, still more complete.

The essential parts of the digestive system having been already noticed, do not call for further remark, save that the first flexure of the intestine being towards that side of the body on which the heart is situated, the flexure is accordingly said to be "hæmal," a term employed in opposition to the name "neural;" and this structural character forming a further distinctive feature between the Polyzoa and Tunicata.

The heart in the Tunicata consists of a simple contractile tube (Fig. 69, C, *f*), unfurnished with valves, and open at each extremity. The circulation in these animals is further to be noticed, inasmuch as it appears to be periodically reversed. The blood thus flows for a certain time in one direction, being propelled by the movements of the heart towards one end of the organ; a reversion of its action, however, takes place, and apparently within a given time, the blood being now driven in the opposite direction, and towards the other extremity of the tube. "The two ends of the heart," to use Huxley's expression, "are alternately arterial and venous."

The respiratory function is performed by the "branchial" sac (*c*), the structure and relations of which it will be unnecessary further to notice. The process by which provision is made for the admission to the sac of fresh water, and for the expulsion of the effete water of respiration, will be readily understood. The venous blood is exposed in the vessels of the branchial sac to the action of the oxygen contained in the water admitted to the sac by the oral aperture, and is thus aërated; the effete water of respiration being sent directly from the branchial sac into the "atrial" chamber, with which the former cavity is in communication; a process aided materially by the cilia of the branchial chamber, which create currents in the direction of the "atrial" sac. From the latter cavity, the effete water is expelled by the second or atrial aperture, and sometimes with considerable force, when, as before observed, these creatures are irritated or disturbed.

The nervous ganglion (*o*) is situated, as in the Polyzoa, between the oral and anal apertures.

The great majority of Tunicata are hermaphrodite, the reproductive organs (*i*) being intimately associated with the intestine, and the efferent generative ducts (*k*) opening into the "atrial" chamber.

Classification.—A satisfactory classification of the Tunicata is still to be desired, but ordinarily the group is divided into three principal divisions, distinguished by the relations of the individual polypides to each other. Thus, in the (*a*) *Simple Ascidians*, represented by the *Ascidiadæ*, or Common "Sea-squirts," the animals are simple: in the (*b*) *Social Ascidians*, represented by the *Clavellinidæ*, the animals are compound, the individuals being connected by tubular prolongations of the "test" or outer tunic, to which the term "stolons" is applied; and in the (*c*) *Compound Ascidians*, represented by the *Botryllidæ*, the individual polypides are still more intimately connected, the "tests" being fused together, and a common mass being thus formed. In addition to these groups, we must add other two families—those of the *Salpadæ* and *Pyrosomidæ*—in which are included free and oceanic forms; these latter also exhibiting certain peculiarities of structure and habits, which render them rather aberrant members of the class.

Of the *Simple Ascidians*, the *Ascidia virginea* (Fig. 69, A), and the *Cynthia quadrangularis* (Fig. 69, B), may be selected as examples. The *Clavellina lepa-*

diformis (Fig. 70, C) represents the *Social* variety; the branchial and atrial apertures being shown at *a* and *b* respectively, and the connecting processes or "stolons" at *s s*, on which young reproductive buds (*c c*) are figured. The *Botryllus violaceus* (Fig. 70, B) may be cited as exemplifying the *Compound* forms: the common "test," formed by the coalescence of the individual tunics, is figured at *c c*, the separate branchial apertures at *a*, and in the centre of the disc the common "atrial" aperture (*b*) is depicted.

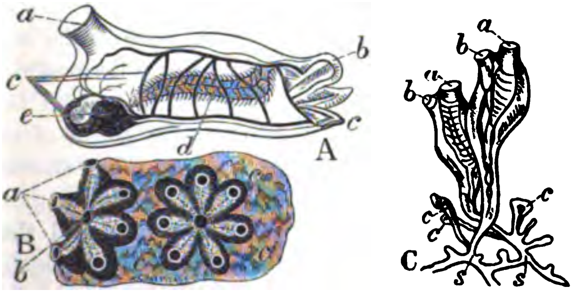


Fig. 70. TUNICATA.

A, Anatomy of *Salpa maxima*: *a*, anterior orifice; *b*, posterior orifice; *c c*, points of attachment to neighbouring *Salpæ*; *d*, branchial sac; *e*, heart, surrounded by viscera. B, *Botryllus violaceus*, a "Compound" Ascidian, showing "branchial" orifices (*a*); common "atrial" aperture (*b*), and common test (*c c*). C, *Clavellina lepadiformis*, exemplifying the "Social" Ascidians: *a a*, "branchial" orifices; *b b*, "atrial" apertures; *c c c*, reproductive buds or "Zooids" in various stages of development, springing from the connecting media or "stolons," *s s*.

The *Salpadæ* are represented by the *Salpa maxima* (Fig. 70, A): these forms are free and oceanic in their habits, and exist in two distinct states, exhibiting thus a series of phenomena identical with those observed in certain Hydrozoa, and to which the collective term "alternation of generations" was applied. The solitary *Salpæ* give rise to chains of Zooids, which remain connected, and thus form throughout life a compound organism. Each of the individual Zooids of this chain, one of which is represented in the figure, gives origin in turn to solitary individuals, from which again the compound organisms are produced. The structural features of the *Salpa* are essentially similar in its connected and free state, and correspond in detail to the typical Tunicate structure already described. Thus at *a* (Fig. 70, A), the anterior and branchial aperture is observed, and at *b* the posterior orifice. The branchial sac is figured at *d*, and the viscera generally at *e;* whilst at *c c* the points of attachment to the chain of *Salpæ* are seen. The "alternation of generations" is therefore here observed to great advantage, although it must be borne in mind that this term does not meet with very general acceptation, inasmuch as the solitary individuals produced by the connected chain of *Salpæ* are alone regarded as true embryos; whilst the compound chain from which they spring is accordingly looked upon as a "highly individualised generative organ." Accepting this view, the so-called "alternation of generations" can no longer be regarded as a term at all explanatory or even correct; since the process, as above defined in the case of *Salpa*, consists merely of a process of development, peculiarly altered and intensified. The solitary *Salpa* is thus the true homological individual; the *Chain-Salpa* being regarded as merely the generative organ and product of the solitary form.

The *Pyrosomidæ*, represented by the *Pyrosoma*, are also free and oceanic, and also exemplify the Compound forms. These organisms exist in the seas of tropical climates as elongated tubes, the tube being formed by the union and coalescence of the tests. As the name implies, the *Pyrosomidæ* possess a considerable luminosity, this property enabling them to appear in the dark as little columns or rods of fire.

The chief points in Tunicate structure may thus be briefly summarised:—

1st, The presence of cellulose, a characteristic vegetable product, in the test.

2d, The peculiar relations of the branchial and atrial sacs.

3d, The power of the heart to throw blood either way, and the consequent periodical reversion of the circulation.

4th, The so-called "alternation of generations," observed in certain Compound forms.

Class III. Brachiopoda.—This last class of the Molluscoida is interesting, principally from a palæontological point of view, this group being but sparsely represented by living species, and abundantly exemplified by extinct and fossil forms. The *Brachiopoda* possess near relations with the Polyzoa, but they differ from the latter forms in certain important features. They exist solely as simple organisms, their bodies being enclosed in a "bivalve" shell—that is, a shell consisting of two halves or "valves;" but, at the same time, they are to be carefully distinguished from the ordinary bivalve Molluscs, such as the Oysters and Mussels, these latter forms being of much higher organisation, and differing from the Brachiopoda in many and important particulars.

The shell of the Brachiopod being bivalve, the valves

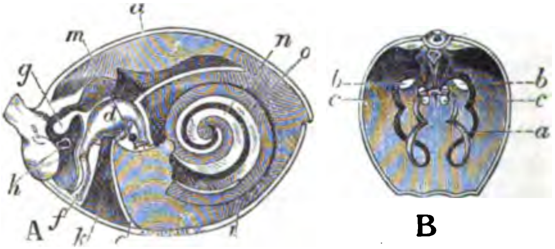


Fig. 71. MORPHOLOGY OF BRACHIOPODA.

A, Diagrammatic section of Brachiopod; *a*, dorsal valve of shell; *b*, ventral valve; *c*, mouth; *d*, stomach; *e*, intestine; *f*, anus; *g*, heart; *h*, aperture of so-called "atrial system;" *k*, adductor muscle; *m*, nervous ganglion; *n*, calcareous loop (carriage-spring apparatus) of dorsal valve, supporting the cirriferous arms (*o*.) B, Internal surface of dorsal valve of *Waldheimia*, showing calcareous loop; *a*, calcareous loop; *b*, impression of posterior adductor muscles; *c*, impression of anterior adductor muscles.

are articulated by an arrangement of toothed projections, springing from the ventral or lower valve, and fitting into corresponding sockets in the dorsal or upper valve. The relative position of the two valves is to be carefully noted, inasmuch as this point forms an element in the distinction between the Brachiopoda and the ordinary bivalve Molluscs. Thus the valves of the Brachiopod shell are spoken of as "dorsal" and "ventral" valves (Fig. 71, A, *a b*); in other words, they lie superiorly and inferiorly to each other. In the Oyster, as typifying the Lamellibranchiate Mollusca, the valves are lateral in position, placed side by side, and are known accordingly as "right" and "left" valves. The "valves" of the Brachiopod shell are further of unequal size, the "ventral" valve being by far the larger and more concave, the "dorsal" valve forming a mere lid, as it were, to the lower and deeper half of the shell. The valves of the ordinary Mollusc are, on the contrary, equivalve, and are typically of the same size.

The shell of the Brachiopod, like that of the Lamellibranchiate Mollusc, is formed and secreted by the soft vascular integument which lines the shell, and to which the appropriate name of "pallium" or "mantle" has been given. The valves are kept in apposition, and are opened and closed by the action of appropriate muscles; the muscles closing the shell are collectively termed the "adductors" (Fig. 71, A, *k*), whilst those which open the valves are known as the "abductors." This arrangement presents a striking contrast to the analogous apparatus in the Lamellibranchiata, in which class the valves are shut by muscles, but opened by the action of an elastic ligament; this latter arrangement being more simple and primitive, and evincing a minor degree of specialisation to that observed in the Brachiopoda, in which class the muscular system attains a development relatively higher and more perfect than any other part of their organisation. The ventral valve is furnished with a prominent projection or "beak," which, in some cases, is perforated by an aperture, through which a fleshy stalk or peduncle passes (Fig. 72, 1), and by this latter the animal attaches itself to fixed objects. Internally the dorsal valve is usually provided with a peculiar calcareous framework (Fig. 71, B, *a*), to which the name of "carriage-spring apparatus" has been applied. This consists of a twisted calcareous loop, the office of which is to support the two elongated "arms" (Fig. 71, A, *n o*) characteristic of the group, and from which the class derives its name. From a fancied resemblance to the old oil-lamps of Eastern countries, the familiar name of "Lamp-shells," applied to the Brachiopoda, has been derived.

The viscera of the animal occupy but a limited part of the internal space of the shell, being confined to the portion within the arms of the calcareous loop. The large and extensile arms (Fig. 71, A, *o*) fill the remaining space; these organs, when at rest, being coiled up within the shell. These arms take their origin from each side of the mouth, and are fringed along their entire edges with "cirri," or delicate processes, the "cirri" being fringed in turn by vibratile cilia. These organs are homologous with the tentacles of the Polyzoa, and they may be considered as corresponding in function also to these latter organs, inasmuch as they aid in sweeping food-particles toward the mouth, and further subserve the function of respiration.

The mouth (Fig. 71, A, *c*), is unprovided with a dental apparatus; a short œsophagus terminates in a globular stomach (*d*), from which an intestine (*e*), with a neural flexure, proceeds, to terminate (*f*) sometimes in a distinct anus, sometimes cæcally or blindly in the middle line. A distinctly developed liver lies near the stomach.

The circulatory apparatus of the Brachiopoda generally consists of a distinct heart (*g*) and vascular system. A peculiar system, termed the "atrial" system, ramifying in the mantle-lobes, and which communicates by distinct openings (*h*) with the external medium, was long thought to represent a part of the true circulatory system, but later researches show that the function of the "atrial" system is in all probability excretory, in serving to convey away the products of the reproductive apparatus.

The function of respiration is performed by the arms (*o*), the ciliated appendages of which would seem to render them peculiarly fitted for this office. The "mantle" itself was long thought to be the chief seat of the respiratory process, and from this opinion the name "*Palliobranchiata*," or "mantle-breathers," was formerly, and occasionally still is, employed to designate the Brachiopoda. This supposition, however, is now proved to be erroneous, the mantle taking little or no share in the respiratory process.

The nervous mass (*m*), as before, is situated between the mouth and anus. The generative organs exist in close proximity to the liver and other viscera, and appear, as previously remarked, to possess certain close relations with the so-called "atrial" system. The Brachiopoda resemble the members of the preceding groups, in that the sexes are contained in the same individual.

The Distributional relations of the Brachiopoda are exceedingly interesting and characteristic. Viewed geologically, they attained a high development and an immense antiquity, and in former epochs of this world's history occupied a position, relative to other forms, similar to that now held by our ordinary shell-fish; these old Brachiopods abounding in the seas of past ages, as the Oysters and Mussels now abound in the oceans of to-day.

Geographically considered, or with reference to their distribution in space, an equally striking contrast to their past life is observed. But few of these forms are represented by living species, and the area over which the existing Brachiopods are spread is of very limited extent: the seas of the Eastern Hemisphere and coasts of Australia being the principal localities tenanted by the Brachiopods of the present day.

CLASSIFICATION.—Three principal types are to be noticed among living Brachiopods. The first group, that of the *Craniadæ*, represented by the solitary genus *Crania*, is distinguished by the absence of a stalk or peduncle, the animal being fixed directly to the sea-bottom by the ventral valve. The *Terebratulidæ*, including the most familiar of living forms (*Terebratula* and *Waldheimia*), form examples of the second type, and are distinguished by the possession of a muscular peduncle, springing from the beak of the ventral valve, and by which the animals attach themselves to fixed objects. The *Lingulidæ* exemplify the third group, and present characteristic forms, of which the *Lingula anatina* (Fig. 72, 1) is the most familiar. The valves of the shell in *Lingula* are nearly equal in size, and the fleshy peduncle passes out from between the valves, instead of through a special aperture, as in *Terebratula*. The "arms" in *Lingula* are unsupported by calcareous loops. The *Lingula* is further to be noted, inasmuch as its palæontological relations are of no ordinary kind. This form makes its appearance in one of the oldest series of rock-formations—the Cambrian rocks (Fig. 72, 2)—and being still in existence, has thus been persistent through time. The Silurian epoch—which included the Cambrian rocks above mentioned—has, from the abundance of fossil Brachiopoda, been not inappropriately termed the "Age of Brachiopods." The most important of extinct genera are those included under

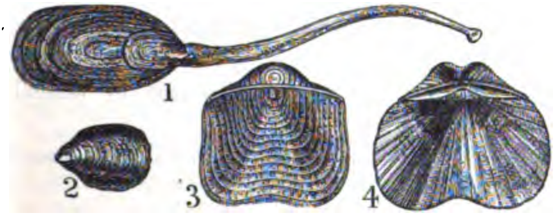


Fig. 72. BRACHIOPODA.

1. *Lingula anatina*, an existing Brachiopod, showing peduncle or stalk. 2. *Lingula Davisii*, a fossil Brachiopod from the *Cambrian* system. 3. *Producta punctata* (*Carboniferous* Limestone), 4. *Spirifer princeps* (*Carboniferous*).

the terms *Productidæ* (*Productus*), (Fig. 72, 3), and *Spiriferidæ* (*Spirifer*), (Fig. 72, 4).

The chief points in Brachiopodous structure may be summarised under five heads:—

1st, The relations of the valves of the shell, the valves being respectively termed "Dorsal" and "Ventral."

2d, The valves opened and closed by muscular action.

3d, The calcareous loop of the Dorsal valve, usually supporting the

4th, Cirrous arms, subserving respiration.

5th, The Distributional relations of the Brachiopoda; their great abundance as extinct organisms, and comparative scarcity as living forms.

CHAPTER XV.

MOLLUSCA PROPER.

General Characters and Classification of Mollusca Proper—General Characters of Lamellibranchiata—Classification.

In addition to the principal characteristic before alluded to—namely, the superior organisation of the nervous system—the Mollusca Proper are distinguished from the Molluscoida by the possession of a well-defined heart, consisting, in the typical forms, of two chambers. In this higher section, an external shell is generally present, and this may consist either of two pieces—when it is said to be "bivalve;" of a single piece, when it is termed "univalve;" or, in a few cases, the shell may be composed of a number of pieces, the term "multivalve" being applied to this latter condition.

A rather arbitrary mode of classification divides the Mollusca Proper into two primary groups: the *Acephala*, or "headless" Mollusca, characterised by the absence of a distinct head, and including but a single class, that of the *Lamellibranchiata*. In the remaining three classes—*Gasteropoda*, *Pteropoda*, and *Cephalopoda*—a distinctly differentiated head is present, these latter groups being accordingly included under the term *Encephala* or *Cephalophora*. The presence of a dental apparatus in these three latter groups has given rise to the term *Odontophora*, a name used synonymously with *Encephala*.

Section A. ACEPHALA.	CLASS IV. LAMELLIBRANCHIATA.
Section B. ENCEPHALA. (ODONTOPHORA).	CLASS V. GASTEROPODA. CLASS VI. PTEROPODA. CLASS VII. CEPHALOPODA.

CLASS IV. LAMELLIBRANCHIATA (*Conchifera*). To this class belong all our ordinary shell-fish, such as Mussels, Oysters, Cockles, etc., and which are accordingly distinguished by the possession of a bivalve shell, and by the peculiar structure of their breathing apparatus, which, as the technical name of the group indicates, consists of "lamellar," or plate-like gills, two of which are usually situated on each side of the body. The valves of the shell are, in the present instance, denominated "right" and "left," the valves being placed laterally, or side by side, a feature which, as previously mentioned, serves to distinguish the present group from the *Brachiopoda*, in which class the valves are situated "dorsally" and "ventrally." The valves, being of equal size, are said to be "equivalve," whilst they are also "inequilateral," each valve being developed more on one side than on the other. Roughly speaking, each valve is more or less conical in shape, and to the apex of the cone, which, as the shells are inequilateral, is placed more to one side of the shell than to the other, the term "umbo," or "beak" (Fig. 73, A, B), is applied. The position of this "umbo" assists in the determination of the various sides and aspects of the shell, since the "beak" points towards the "anterior" side of the shell, at which the mouth is situated. The "posterior" border of the shell, accordingly, is that from which the "umbones" are turned away, and this side of the shell is much more elongated than the "anterior" border, which latter forms, in consequence, the shorter half of the shell. The "dorsal" and "ventral" surfaces of the shell are easily determined—the "dorsal" aspect being that by which the valves are articu-

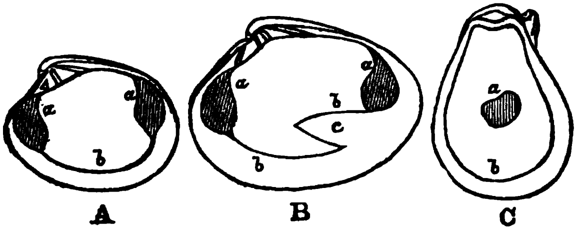


Fig. 73. MORPHOLOGY OF LAMELLIBRANCHIATE SHELLS.

A, Right valve of *Cyprina islandica*, showing the two muscular impressions, *a*, *a* (*Dimyaria*), and the entire pallial line, *b*. The "umbo," or "beak," of the shell, points to the left hand side of the figure, and determines the left of the muscular impressions as that of the anterior adductor muscle, the other and right hand impression being that of the posterior adductor.

B, Right valve of *Cytherea chione*, showing the muscular impressions, *a a*, and an indented pallial line, *b*, with a pallial sinus, *c*.

C, Valve of the Oyster (*Ostræa*), showing a single muscular impression *a*, (*Monomyaria*), and an entire pallial line, *b*.

lated to each other, and the "ventral" surface that along which the valves open.

The valves are articulated together by means of a set of projections, or "teeth," situated on one valve, and which fit into and interlock with corresponding depressions and teeth on the other valve; the structure known as the "external ligament," and which is attached to the "umbones" of the valves, serving to strengthen and retain in position the hinge-like apparatus thus formed. An "internal ligament," or "cartilage," situated within the hinge-lines of the shell, also exists, and, together with the "external ligament," forms the agency by means of which the valves are opened. The "internal ligament" is composed of highly elastic fibres, which are compressed by the closure of the valves; whilst the "external ligament," passing between the valves on their outside surface, is put on the stretch when the valves are shut. The opening of the shell is, therefore, a purely mechanical action, these ligaments opening the valves in virtue of the mere elasticity with which they are endowed, when the muscles which close the valves are relaxed. The muscles (adductors), the function of which is solely to approximate the valves to each other, and so to close the shell, exist generally to the number of two, their situation being indicated on the shell by corresponding impressions. The muscle situated in the neighbourhood of the mouth, and consequently at the anterior border of the shell, is known as the "anterior adductor" (Figs. 73 and 74, *a*); whilst the remaining muscle, situated posteriorly, is termed the "posterior adductor" (Fig. 74, *l*). In certain families of the Lamellibranchiata, typically represented by the Oysters (Fig. 73, C), and Scallops, only a single muscle exists; this single organ being regarded as homologous with the "posterior" muscle of the other and majority of forms. Lastly, it may be noticed that the foregoing feature in the morphology of this group has been employed as the basis of certain systems of classification; the Lamellibranchiata being, according to this mode, divided into two sections, in the first of which, that of the *Monomyaria*—those forms possessing but a single muscle (Fig. 73, C)—are included; whilst the *Dimyaria* (Fig. 73, A, B) include those in which two muscles are found.

The internal surface of the shell is lined by a soft vascular membrane, enveloping the viscera generally, and appropriately termed the "pallium," or "mantle" (Fig. 74, *r*, *r*), to the form and relations of which it is necessary to direct particular attention. The "mantle" is the chief agent in the formation of the shell, and whilst the secretion of calcareous material seems to take place over its entire surface, the edges of the structure appear more especially to be provided with the secreting glands. The connections and relations of the two "lobes," or halves of the mantle, afford means of classifying and subdividing this extensive group; since we arrange the Lamellibranchiata in two distinct and characteristic divisions, accordingly, as the mantle-lobes are arranged after one or other of two fashions. In the first and simplest type, the mantle-lobes are unconnected and simply attached, each, to the edge of the valve it lines, and the margins of the valves are thus free along their entire length. In the second type, the mantle-lobes are more or less completely united by their edges, and are drawn out to form siphons or tubes of considerable length, for the admission of water to, and its expulsion from, the gills. These typical siphons are retractile, and provided with special muscles, by means of which they can be withdrawn into the shell. An inspection of the shell of any particular Lamellibranchiate at once shows whether the animal in question possessed these retractile siphons or not, since the line by which the mantle was attached to each valve is clearly marked in the shell, the line being known as the "pallial line" (Fig. 73, *b*). Accordingly, in those shells of the first type, in which no siphons are present —or, as will be presently explained, where the siphons were non-retractile—the "pallial line" runs in an even and unbroken course along the edge of the shell (Fig. 73, A); in other words, it is "entire." Whilst in the second type of shell, the animal of which possessed retractile siphons, the "pallial line" is observed to curve inwards posteriorly, and so to form an indentation known as the "pallial sinus" (Fig. 73, B, *c*); the "sinus" corresponding to, and indicating the situation of, the "retractor" muscles, by means of which the siphons could be retracted within the shell. Between these two typical extremes a series of forms, exemplifying intermediate conditions of the mantle-lobes, are observed. Thus, we may advance from the first and simplest condition (*Ostrea*), (Fig. 73, C), where the mantle-lobes are free and ununited throughout their entire length, to other forms in which the mantle-lobes are united along a certain portion of their extent (*Mytilus*), two special apertures being now provided for the admission of water to and its expulsion from the gills; whilst in the next stage we find these two apertures being prolonged into tubes or siphons (*Cardium*), which, however, are of limited size, and not capable of being retracted within the shell. In each of these instances, therefore, the "pallial line" is entire and simple. But when we arrive at the next and last stage, the perfection of this arrangement is attained; the siphons, in this latter case, being retractile, provided with special retractor muscles, and the "pallial line" exhibiting a deflection in its course; this deflection or "sinus," as previously remarked, indicating the site of the retractor muscles of the siphons. The illustrations depicted at Fig. 73 will serve to render this arrangement more intelligible to the reader.

Those Lamellibranchiates, therefore, in which the pallial line is simple and entire, form the section *Intego-Pallialia* (Fig. 73, A, C); whilst those forms in which the pallial line is indented, and in which, accordingly, the siphons are retractile, are included in the division *Sinu-Pallialia* (Fig. 73, B). This distinction, it must be remembered, is subsidiary—so far as the classification of the group is concerned—to another and primary consideration, namely, the presence or absence of respiratory siphons. The special features of this subject will be noticed when treating of the subdivisions of the group.

In the Lamellibranchiata a muscular organ, applied to a variety of uses, and termed the "foot" (Fig. 74, *m*), is very generally present. This organ is usually situated anteriorly, the mouth opening at its base. It varies greatly in form and development, attaining its greatest degree of perfection amongst the Dimyarian bivalves; whilst among the Monomyarians it exists in a very rudimentary and abortive form. With regard to the various functions to which the foot is applied, these are many and various. Thus, in the Cockles, the foot is used to enable the animal to effect leaps of very considerable extent. In the *Solenidæ*, or "Razor-shells," it subserves the function of a boring-organ, being employed by these forms to burrow in the sand; whilst in the Pinna, or more familiarly in the common Mussel, the foot is applied to the manufacture of a peculiar thread-like structure, known as the "byssus," and by means of which these bivalves attach themselves to fixed objects. "Whoever," says Mr. Gosse, "has attempted to wrench up a Mussel from one of those shallow rock-pools, in which they lie as closely packed as paving-stones, will have had proof of the great strength of these threads, no small violence being required to detach one." The threads of which the "byssus" is composed are secreted at first as a viscid fluid, in a groove or fissure situated on the under-surface of the foot. This shortly, on exposure to the air, or by contact with the water, hardens into a thread-like consistency, and the extremity of the foot being applied to a fixed surface, and then retracted, the thread thus formed is pulled out of the groove and added to the mass of fibres previously secreted; a fresh secretion being in turn prepared. The "byssus" of the Pinna, a form allied to our common Mussel, and found on the Mediterranean coasts, is of a fine silky texture, and is used by the inhabitants of the Sicilian and Italian coasts in the manufacture of a strong durable fabric.

The digestive system comprehends a distinct mouth (Fig. 74, *b*), situated between the base of the foot and the anterior adductor muscle (*a*), and provided with four small membranous "palpi," but destitute of any dental apparatus—a feature which affords a strong contrast to the arrangement in the succeeding classes, in which a distinct masticatory apparatus is present. The stomach (*c*) is large, and the intestine (*d*), after a few convolutions—its first flexure being neural—and after passing through the substance of the foot, and in some cases perforating the walls of the heart, terminates in a distinct anus (*e*), situated posteriorly, and usually in close proximity to the posterior adductor muscle (*l*). A capacious liver (*f*) exists, and pours its secretion by various ducts into the stomach.

The hæmal or blood-vascular system is typically represented by a two-chambered heart, consisting of an auricle and ventricle (Fig. 74, *h*, *i*), although two auricles and a ventricle would appear to be present in several instances. The auricle, or lesser chamber (*h*), receives the purified blood from the gills, the ventricle, or larger cavity (*i*), propelling it through the system. The venous blood is returned to the gills for aëration by the venous trunks, and without the direct agency of the heart, which is thus seen to be a purely *systemic* organ, being occupied solely in sending the blood through the body.

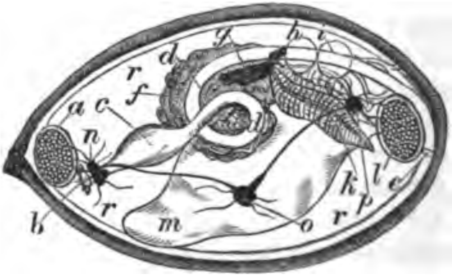


Fig. 74. Diagram of Lamellibranchiate (the left valve having been removed, the Viscera are represented *in situ*).

a, Cut edge of anterior adductor muscle; *b*, mouth; *c*, stomach; *d*, intestine; *e*, anus; *f*, liver; *g*, generative organs; *h*, auricle, and *i*, ventricle, of heart traversed by the intestine; *k*, gill; *l*, posterior adductor muscle, also cut across; *m*, foot; *n*, "cephalic" or "supra-œsophageal" ganglia; *o*, "pedal" ganglia; *p*, "branchial," or "parieto-splanchnic" ganglia; *r r r*, mantle.

The respiratory organs form a characteristic feature of this class, these structures existing in the form of four plate-like (lamelliform) gills, disposed two on each side of the body. Each gill (*k*) consists of membranous "laminæ," or plates, highly vascular, and richly supplied with vibratile cilia, the entire structure of these organs being suited to the constant circulation of water and the consequent and due aëration of the blood. The means whereby water is admitted to the gills having been already described, it only remains to notice that in those forms in which siphons exist, one of these respiratory tubes is termed the "inhalent," whilst the other is known as the "exhalent" siphon; fresh water being admitted to the gills by the former, whilst the effete water of respiration is expelled by the latter tube (Fig. 75, *a*).

The nervous system, in accordance with the typical arrangement, consists of the three principal ganglia, known respectively as the "cerebral" (Fig. 74, *n*), "pedal" (*o*), and "branchial" (*p*) ganglia. To the latter the term "parieto-splanchnic" ganglia is sometimes applied, the name being given to this centre, from the fact of its supplying the walls (parietes) of the body, and the viscera generally.

The sexes in the majority of Lamellibranchiates are situated in separate individuals, but several forms appear to be hermaphrodite. The generative organs (Fig. 74, *g*) are imbedded in the general mass of the viscera.

The habits of these bivalves, together with their habitats, are very varied. The majority exist in a free and unattached condition, inhabiting the sandy shores of the world. Others (such as the *Solenidæ*) burrow in the sand; whilst others, exemplified by the *Pholas* and *Teredo* (Fig. 75, *a*, *b*), excavate holes and dwelling-places in rocks and in wood; the shells constituting the chief agency by which these operations are carried on, and the structure of these organs being peculiarly fitted for the performance of this especial duty. The function of the elongated siphon of the Pholas and its neighbours, in affording means of communication with the external world, as the creature lies ensconced in its burrow, will readily be perceived. The Oysters and their allies, again, attach themselves directly by their shells to the ground; whilst the Mussels, the Pinnæ, and their neighbours, moor themselves to fixed objects by means of the "byssus," which forms so characteristic a feature of these Molluscs.

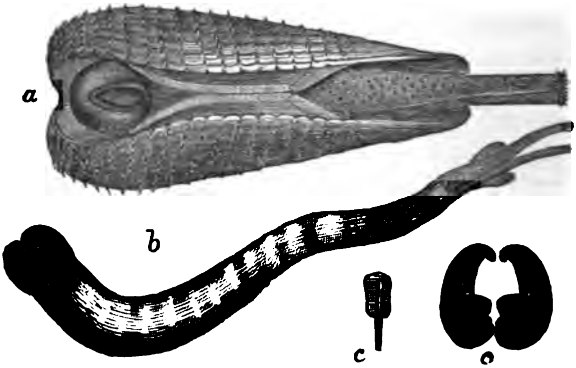


Fig. 75. LAMELLIBRANCHIATA.

a, *Pholas dactylus*, showing the siphons; *b*, *Teredo norvegica*, the "Ship-worm;" *c*, *c*, detached shells of *Teredo*.

CLASSIFICATION.—The *Lamellibranchiata* are divided into two orders, distinguished respectively by the presence or absence of respiratory siphons. In the

Asiphonida, forming the first of these two orders, no siphons exist, the mantle-lobes being united, and the pallial line being simple or "entire."

In the *Siphonida*, respiratory siphons are present, but the extent to which the mantle-lobes may be united varies considerably, as previously remarked, throughout the group.

To the *Asiphonida* belong the families *Ostreidæ* (Oysters), *Mytilidæ* (Mussels), *Unionidæ* (Fresh-water Mussels), and other but less familiar forms.

The *Siphonida* are divided by the presence or absence of a "pallial sinus" into two sections. In those forms (*Integro-pallialia*) in which the pallial line is entire the siphons are non-retractile; whilst in those (*Sinu-pallialia*) in which a "pallial sinus" exists, the siphons are retractile, and exhibit a correspondingly high degree of development.

Of the families included in the first section (*Integro-pallialia*) of this latter group, the most familiar are the *Tridacnidæ* (Clam-shells) and the *Cardiadæ* (Cockles); whilst the second section (*Sinu-pallialia*) comprises the familiar *Myacidæ* (Gapers), *Solenidæ* (Razor-shells), and the *Pholadidæ* (Pholas, Teredo), of which illustrative examples are depicted in Fig. 75.

CHAPTER XVI.

MOLLUSCA PROPER.

CLASS V. GASTEROPODA.

General Structure of Gasteropoda—Classification.

THE consideration of this class introduces us to those Molluscs in which a distinct head is present, and to which the collective terms *Encephala* or *Cephalophora* are applied. The members of this group are distinguished by the possession of a broad locomotive disc or "foot" (Fig. 78, *a*), situated on the ventral or inferior surface of the body, and from the presence of which the name Gasteropoda or "belly-footed" Molluscs is derived. A familiar instance of the Gasteropod and its foot is seen in the common Snail or Whelk (Fig. 79, A), progression being in either case effected by the ventral disc.

The shell, when present, is either "univalve," that is, composed of a single piece; or it may be composed of many pieces, as in Chiton, when it is said to be "multivalve." In no Gasteropod is the shell "bivalve." Finally, in certain members of this group the shell is of rudimentary structure, or may be absent altogether. The typical form of the Gasteropod shell is that of a hollow cone, and this in its simplest state is seen in the case of the Limpets, in which the shell exists as "a simple cone, placed upon the back of the creature, which it completely covers, and upon which it is evidently moulded." As in the previous class, the shell is secreted by the "mantle," certain portions of which, however, to be afterwards noticed, are more especially devoted to the function of enlarging and extending the shell. If we now suppose that the simple shell of the Limpet is drawn out into an elongated cone, and that this cone is twisted in a spiral manner round a central axis or "columella," we shall then have a sufficiently correct idea of the principal and typical modification of the shell in this class; the plan of structure on which the shell is thus constructed being known as the "spiral univalve." The spiral "coils" of the shell, or "whorls," as they are technically designated, are generally turned towards the right side, the shells in which this arrangement is found being known as "dextral." In a few forms, however, the spire is turned towards the opposite (left) side, in which case the shells are termed "reverse" or "sinistral."

The body in the Gasteropoda, in consequence of this spiral arrangement, is generally unsymmetrical; a greater preponderance being given in the majority of instances to the right side. In some naked or shell-less forms, however, the body is equally developed on each side, the symmetry being thus perfect.

The mantle forms a continuous covering to the body, and, as in the Lamellibranchiata, appears to be capable of the deposition of calcareous matter over its entire surface. The last or "body" whorl of the shell is lined by a thickened portion of the mantle (Fig. 78, *k*), to which the name of "collar" is applied, and upon this latter structure devolves the function of more particularly extending and adding to the size and dimensions of the shell.

The aperture of the shell presents several features of interest, the conformation of the margin of the "body-whorl" exhibiting certain variations of structure throughout the group. The margin of the aperture is known as the "peristome," and in one description of shell the peristome is "entire" and unbroken; this arrangement being characteristic of the *Phytophagous* or plant-eating Gasteropoda. In the second type, the margin is indented by a notch, or may be elongated to form a canal for the reception and protection of a respiratory tube or "siphon;" this latter feature being indicative of the *Carnivorous* or Flesh-eating propensities of this latter group. In certain instances, two of these siphons, termed respectively "anterior" and "posterior," are found; this arrangement in these latter forms, however, being entirely independent of the nature of the food. The shells of the former description, in which the margin of the aperture is entire, are accordingly known as "Holostomatous" shells (Fig. 76, *a*); whilst those in which the peristome is notched or indented, and in which siphons exist, are termed "Siphonostomatous" (Fig. 76, *b*) Gasteropods.

The "foot" (Fig. 78, *a*, and Fig. 79, A) in the typical Gasteropoda, is used exclusively for locomotive purposes, movements being effected by successive contractions of the segments, into which the "foot" appears to be divided. The "foot" varies in development throughout the group, but in general appears to attain its greatest perfection in the shell-bearing forms, whilst in the naked species the "foot" is small and rudimentary, and appears to be used, in some instances at least, as a natatory or swimming organ (Fig. 80, *e*). The "foot" can be retracted within the shell of the creature, and its posterior surface is, in the majority of instances, furnished with a calcareous or horny plate, termed the "operculum," which accurately fits the aperture of the shell, and thus serves to close the orifice when the creature has withdrawn into its abode. The "operculum" (Fig. 78, *b*; Fig. 79, A, *a*) has been regarded by some zoologists as analogous to the second valve of the Lamellibranchiate shell, whilst

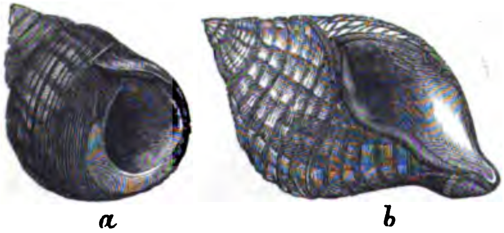


Fig. 76. MORPHOLOGY OF GASTEROPODOUS SHELLS.

a, The Common Periwinkle (*Littorina littorale*), a *Holostomatous* shell; *b*, the Purple-Whelk (*Purpura lapillus*), a *Siphonostomatous* shell.

other authorities maintain its affinity with the "byssus" or foot-secretion of certain members of that class.

The mouth (Fig. 78, *d*) is generally situated on the lower surface of the well-marked head, but may be borne, as in the Whelk, on an elongated protrusible proboscis. In the mouth of all Gasteropods a peculiar organ, termed the "tongue," "lingual ribbon," or "odontophore" (Fig. 77), exists; and in addition to this organ, horny jaws are sometimes also present. The "odontophore," which in most Gasteropods attains a considerable length, consists (as in the Limpet, Fig. 77, C, D) of an elongated ribbon-like structure, supported by two cartilaginous rests, to which the muscles moving the organ are also attached. On submitting this structure to microscopical examination (Fig. 77, D), transverse rows of siliceous or flinty teeth are seen to be imbedded in its substance. The anterior or free extremity of the "odontophore" is of hard consistency, whilst the posterior and attached portion is compara-

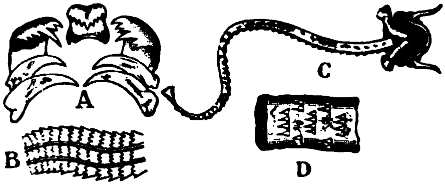


Fig. 77. TEETH AND MASTICATORY APPARATUS OF GASTEROPODA.
A, Portion of odontophore of *Velutina* (enlarged). B, Portion of odontophore of Whelk (*Buccinum undatum*) magnified (Woodward). C, Head and odontophore of the Common Limpet (*Patella vulgata*). D, Portion of the same, greatly magnified, to show the transverse rows of siliceous teeth.

tively soft. The growth of the organ takes place from the posterior extremity, and as the anterior part is worn away by the constant attrition, new growths of substance are as continually taking place at the posterior portion; these fresh growths gradually supplying the place of the worn portions, and in turn assuming the necessary hardness for the due performance of the triturating process. In the Whelk a modification of this structure is observed, the "odontophore" (Fig. 77, B), in this case, being contained within the muscular proboscis; and being supported on two cartilaginous plates, by the movements of which the "odontophore" is made to act somewhat after the fashion of a chain-saw, and in this manner effectually to rasp down and triturate the hard substances upon which these creatures may subsist. The important part also played by this structure, in the boring operations of the Whelk, whereby that creature erodes the shells of other Molluscs, and upon the soft parts of which it feeds, will readily be perceived.

Salivary glands (Fig. 78, *e*) pour their secretion into the mouth, from which an œsophagus leads to a distinct stomach (*f*), in the mucous or lining membrane of which, calcareous projections or teeth, serving further to triturate the food, may be developed. The intestine (*g g g*) is generally of considerable length, its first flexure being in the majority of instances hæmal, whilst in other cases it turns first towards the neural aspect of the body. The anus (*h*) is in general situated close to the margin of the branchial or respiratory chamber (*n*), and thus in close proximity to the head and anterior portion of the body. The liver (*i*) is large, and intimately connected to the stomach and intestines, the latter organs being firmly invested in its voluminous folds.

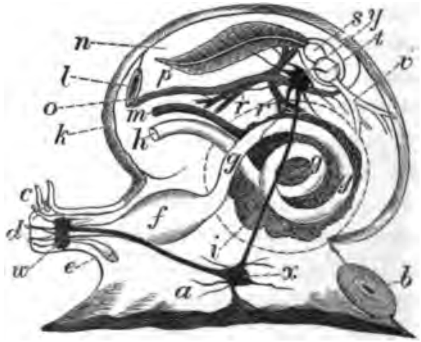


Fig. 78. DIAGRAM OF GASTEROPOD.

a, Foot; *b*, operculum; *c*, tentacles, at the base of which an auditory vesicle is represented; *d*, mouth; *e*, salivary gland; *f*, stomach; *g g g*, intestine; *h*, anus; *i*, liver, the dark mass represented towards the upper part of the liver representing the generative organs; *k*, cut edge of mantle; *l*, aperture of branchial chamber; *m*, oviduct; *n*, branchial or gill chamber; *o*, vascular "diaphragm," or floor of respiratory chamber, forming, in the Land Gasteropods, the breathing organ; *p*, gill; *r r*, venous trunks, carrying venous blood to gills; *s*, auricle, and *t*, ventricle, of heart; *v*, arterial trunks distributing blood throughout the system; *w*, "cephalic" ganglia; *x*, "pedal" ganglia; *y*, "branchial" or "parieto-splanchnic" ganglia.

The heart is situated dorsally, and in the neighbourhood of the respiratory organs. It consists of an auricle (Fig. 78, *s*), or lesser chamber, receiving the purified blood from the respiratory organs, and a ventricle (*t*) or larger chamber, propelling the blood through the system, these two cavities being separated by a distinct valve. The heart in the present instance, like that of the preceding class, is purely *systemic* in function, the blood being conveyed to the gills for purification by the venous trunks (*r r*), but without the agency of the heart.

The respiratory organs of this class vary with the habits of the different forms included within its limits. Thus, in the aquatic forms, true gills (*p*) exist, whilst in the terrestrial species—represented by the Snail—we find a pulmonary or lung sac (*n*) taking the place of gills. The nature and arrangement of the breathing organs have been used as a basis for the classification of the group; and, accordingly, the more minute and differential points will be more appropriately noticed when treating of the various subdivisions of the class. The two chief structural types on which the respiratory organs are constructed, may be briefly alluded to in the present instance. In the Whelk, which may be selected as exemplifying the marine or "Branchiate" Gasteropoda, the respiratory organs exist as plume-like gills or branchiæ (*p*), enclosed in a special chamber (*n*) (branchial chamber), situated on the dorsal aspect of the animal. This chamber is formed by a special fold or reduplication of the mantle, and water is admitted to the contained gills by a special aperture (*l*), or, in many cases, by means of a respiratory tube or "siphon" (Fig. 79, A, *b*). As previously mentioned, two siphons may occasionally be present, in which case one serves as an "inhalent" tube, the other as an "exhalent" channel. In the Snails, on the other hand, exemplifying the terrestrial Gasteropods, breathing is effected by means of a pulmonary or lung chamber (Fig. 78, *n*), situated similarly to the branchial chamber of the aquatic forms. The walls and floor (diaphragm) (Fig. 78, *o*) of this chamber are formed by a highly vascular membrane, in which the minute capillary blood-vessels, carrying venous blood, are very thickly distributed. Air is admitted to the chamber by a special aperture situated on the right side of the neck, and which can be closed at the will of the animal. The walls of this pulmonary chamber appear to contract and expand, and in this manner the inhalation and expulsion of air is duly provided for.

The nervous system is subject to many modifications, and often deviates from the typical arrangement. The three chief ganglia (Fig. 78, *w*, *x*, *y*) are, however, generally to be recognised, the "cerebral" ganglion especially retaining its original position and relations in the majority of instances. The principal modification of the nervous system in the present group appears to be the coalescence of the nervous centres in the region of the head.

Organs of sense are well developed throughout the class. Two eyes, generally supported on stalks (pedunculated), are usually present, whilst a pair of tentacles (Fig. 78, *c*), exercising the sense of touch, are very constant appendages to the head. Auditory, or hearing vesicles, consisting of small cysts, containing fluid and particles of mineral matter (otoliths), are generally found situated at the bases of the tentacles.

Whilst in the majority of instances the sexes in the Gasteropoda are distinct, several members of this group are hermaphrodite, the sexes being contained in the same individual. The bulk of the generative organs is embedded in the mass of the liver, the excretory ducts (Fig. 78, *m*) of the reproductive system opening in close proximity to the anal aperture, and on the right side of the neck. The eggs of the Gasteropoda are enclosed in coriaceous or leathery capsules ("nidamental capsules"), and are agglutinated together in packets or masses, which form common, yet sufficiently curious objects of the shore.

CLASSIFICATION.—The Gasteropoda are primarily divided into two sections, distinguished by their habits, and by the corresponding structure of the respiratory apparatus.

In the first of these sections or sub-classes, that of the *Branchifera*, the respiration is aquatic, and the breathing organs exist typically in the form of gills; whilst the second section or sub-class includes the terrestrial forms which respire by lung-sacs, and which are accordingly known as the *Pulmonifera*. In the *Branchifera* the flexure of the intestine is hæmal; whilst in the *Pulmonifera* it is neural.

The *Branchifera* are divided into three orders:—

Order 1. *Prosobranchiata.*
Order 2. *Opisthobranchiata.*
Order 3. *Nucleobranchiata* (*Heteropoda*).

Order 1. *Prosobranchiata.*—All the members of this group possess a shell, into which the animal can withdraw itself at will. The gills are placed anteriorly to, or in front of the heart, from which circumstance the technical name of the order is derived. The sexes, in the present instance, exist in separate individuals. This group is subdivided into the subordinate divisions of the *Holostomata* and *Siphonostomata.* In the first of these latter sections the margin of the shell is entire; whilst, in the second group, the margin is notched or indented, for the passage of respiratory siphons. Of the families included in the *Holostomatous* section, the most familiar are the *Littorinidæ* (Periwinkles) (Fig. 76, *a*); *Turbinidæ* (Top-shells); *Patellidæ* (Limpets); *Dentalidæ* (Tooth-shells); *Chitonidæ* (Chitons). The best-known families included in the *Siphonostomatous* section are the *Muricidæ*, *Buccinidæ* (Whelks), (Figs. 76 *b*, and 79 *a*), *Cypræidæ* (Cowries); and *Conidæ* (Cone-shells).

Order 2. *Opisthobranchiata.*—In this order the shell is rudimentary, or may be absent: the branchiæ are more or less exposed, and are situated,—as implied by the term *Opisthobranchiate*—towards the posterior extremity of the body. The sexes are united in the same individual.

This order is also divided into two sections, in the first of which, the (*a*) *Tectibranchiata*, the gills are covered by the mantle or by a rudimentary shell. The *Aplysiadæ*, or "Sea-hares," form the most familiar examples of this group, which also includes the *Bullinidæ*, popularly known as "Bubble-shells." Among the *Nudibranchiata*, or "Naked-gilled" members of this order, the well-known "Sea-Lemons" (*Doridæ*), of which a representative form is depicted at Fig. 79, B, are included. The (*b*) *Nudibranchiata* do not possess a shell, and the gills are external, presenting, as depicted in the figure, a beautiful arborescent or branched appearance. The "Sea-slugs" (*Æolidæ*), in which the branchiæ are arranged along the sides of the neck, also belong to this group.

Order 3. *Nucleobranchiata* (*Heteropoda*).—This group embraces a number of seemingly aberrant forms, but which nevertheless exhibit a decidedly higher organisation than the other members of this extensive class. The *Nucleobranchiata*, represented typically by the *Carinaria* (Fig. 80), are free-swimming and oceanic

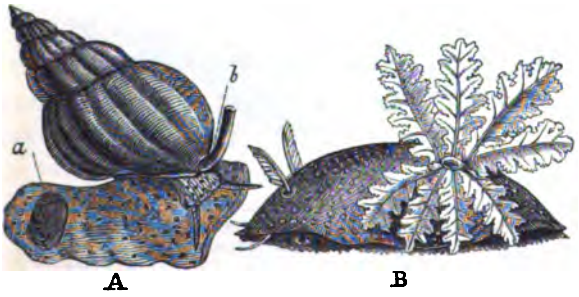


Fig. 79. Gasteropoda.

A, *Buccinum undatum*, the Common Whelk, with extended foot, showing, *a*, the operculum; and *b*, the siphon. B, *Actinocyclus grandiflora*, one of the *Doridæ*, or "Sea-Lemons," showing the arborescent branchiæ in their expanded state.

in their habits, locomotion being effected by means of a curious "vertically flattened, ventral fin-like organ" (Fig. 80, *e*), corresponding to a portion of the ordinary Gasteropodous "foot." A shell may or may not be present. In the *Carinaria* the chief structural peculiarities of the group may be conveniently observed. Thus the mouth, furnished with a proboscis, is depicted at *a*, the tentacles at *b*, the flattened ventral fin-like organ at *e*, and the rudimentary shell covering the branchiæ (*d*) at *c*. The *Carinaria* swims back downwards, propelling itself by means of the ventral fin, which is provided with a small sucker, enabling the creature to attach itself to fixed objects. In other members of this order a well-developed shell is present, and into this the animal can withdraw itself, like other Gasteropods; the aperture of the shell, as in ordinary cases, being closed by an operculum.

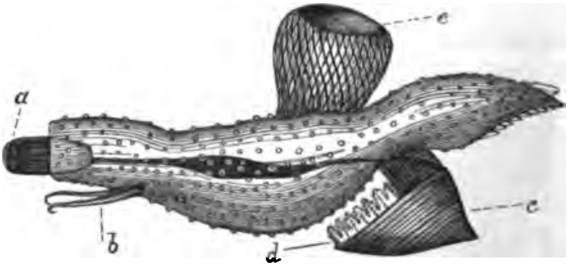


Fig. 80. HETEROPODA. *Carinaria cymbium.*

a, Proboscis; *b*, tentacles; *c*, shell; *d*, branchiæ; *e*, ventral fin-like organ, bearing sucking disc. (The *Carinaria* is represented as swimming in the natural position, namely, back downwards.)

The second sub-class or primary section of the Gasteropoda is that of the *Pulmonifera*, or "lung-bearers," in which the respiration is aërial, the breathing organs consisting of a pulmonary chamber, to which the air is admitted by a distinct aperture. The sexes are united. This section is divided, by the presence or absence of an operculum, into two subdivisions. The *Operculata*, forming the first of these subordinate groups, possess an operculum, and include only a few unimportant forms (*Cyclostomidæ*), allied to the Snails, which latter are included in the *Inoperculata*, in which division an operculum is absent. The shell may be wanting, or rudimentary, in the *Inoperculata*.

The most familiar divisions of this latter group are the *Helicidæ*, represented by our common Land Snails; whilst the *Limacidæ* or Slugs, and *Limnæidæ*, or Pond Snails, also offer familiar examples of the group.

CHAPTER XVII.

MOLLUSCA PROPER.

CLASS VI.—PTEROPODA.

General Characters and Structure of Pteropoda—Classification.

CLASS VI. *Pteropoda.*—The Pteropoda are represented by a limited group of animals, free and oceanic in their habits, and for the most part of small or even minute size. The characteristic structural feature of the group consists in the presence of two muscular wing-like appendages or "fins" (Fig. 81) attached to the sides of the neck, and which, as implied by the technical desig-

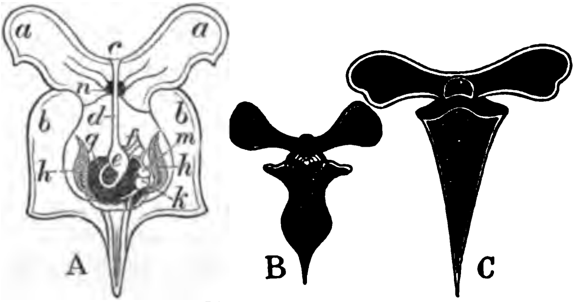


Fig. 81. PTEROPODA.

A, Diagram of Pteropod; *a a*, fin-like lobes or "wings;" *b b*, mantle; *c*, mouth; *d*, œsophagus; *e*, stomach; *f*, anus; *g*, liver; *h h*, gills; *k*, auricle of heart; *m*, ventricle of heart; *n*, nervous ganglia. B, *Cleodora*. C, *Hyalæa*.

nation of the group, constitute the locomotive organs of these creatures. These appendages represent portions of the ordinary Molluscan "foot," peculiarly modified and adapted for the particular function they are intended to subserve. Our knowledge of the class is as yet extremely limited, the habits of the Pteropoda, together with their fragile and minute structure, rendering the careful examination of their forms a matter of great difficulty.

In some species a delicate and symmetrical shell, (Fig. 81, B, C), of glassy transparency, is present; the shell being either of triangular shape, and consisting of a dorsal and ventral plate, or in other cases it is spherical in form. A few genera are naked, and destitute of a shell, this peculiarity serving to class these latter forms as a distinct subdivision of the group.

The characteristic "wings," or "fins" (Fig. 81, A, *a a*), of the Pteropoda are used as natatory organs, these creatures swimming rapidly and in every direction by the action of these structures. Indeed, the elegance and rapidity of their movements have procured for the Pteropoda the familiar name of "butterflies of the sea," their movements in the water imitating closely the flight of their aërial prototypes.

The head appears to be indistinctly marked throughout the group, but is furnished in the majority of instances with eyes and tentacles, the latter organs exercising the sense of touch. In addition to these organs, the head, in certain species, is provided with several "conical appendages," each of which is furnished in turn with an immense number of minute discs. The function of these appendages would appear to be that of a prehensile apparatus.

The mouth (Fig. 81, A, *c*) is situated on the inferior aspect of the head, and is provided with lateral jaws, whilst an armed tongue, or "odontophore," may also be present. An œsophagus (*d*) conducts to a distinct stomach (*e*), which lies imbedded in the substance of a large and well-developed liver (*g*). The intestinal flexure is towards the neural aspect of the body, the anus (*f*) opening behind the wing-like appendage of the right side. Salivary glands are generally present, and the renal or urinary function appears to be subserved by a special organ.

The heart (*k*, *m*) corresponds in structure to that of the typical Molluscan forms, and consists accordingly of an auricle (*k*) and ventricle (*m*), enclosed in an outer sac or "pericardium." Respiration is performed by means of branchiæ or gills (*h*, *h*), which are, however, of a rudimentary description, and which may either be free and unprotected, or enclosed in a special branchial chamber.

The nervous system is represented by a large compound ganglion (*n*), the various and component parts of which form a ring surrounding the gullet, and from which nerves radiate to the adjacent organs and parts. The eyes are of very rudimentary description, and appear to be absent in one genus (*Hyalœa*). The tentacles and "conical appendages" of the head subserve the tactile sense.

The sexes are contained in the same individual, the Pteropoda being thus hermaphrodite. The generative organs occupy a considerable portion of the internal space, and consist of a large ovary, closely connected with the mass of the liver, the oviduct, together with the efferent duct of the testis or male organ, opening in a common aperture close to the anal orifice. In their development the Pteropoda undergo a metamorphosis, the embryonic form being provided with a disc-like membrane or "velum," which, in the adult form, is replaced by the "fins."

In their habits the Pteropoda are carnivorous, subsisting on the minute Crustacea with which the seas they inhabit abound. The Pteropoda swarm in the seas of the Equator, but seem to exist in greatest profusion in the Northern and Arctic oceans, constituting in these regions vast fields of life, through which, it is said, ships may sail for a considerable period. From the exceeding plenty in which a particular genus—*Clio*—abounds in the Northern seas, it has received the popular name of "Whale's-food;" a term applied to it from the supposition that these creatures constitute a great proportion of the food of the Cetacea generally. The Pteropoda, moreover, seem to be nocturnal or crepuscular in their habits, these creatures appearing in myriads on the surface of the ocean on the approach of twilight, or after the daylight has wholly disappeared: to use the words of Professor Rhymer Jones, "each species in fact seems to have its appropriate hours, or rather its appropriate degrees of darkness."

CLASSIFICATION.—The Pteropoda are divided into two orders, in the first of which—that of the *Thecosomata*—the body is enclosed in an external shell, the head being indistinctly marked, and the respiratory organs enclosed in a special cavity. Of this group the best-known examples are the *Hyalæa* (Fig. 81, C), and *Cleodora* (Fig. 81, B). In the second order—that of the *Gymnosomata*—the body is unprotected, a shell being absent, the head, however, being distinct, and the gills of rudimentary description. Of this group, the *Clio*—from the examination of which form the structure and relations of the group have been principally determined—is the typical example.

CHAPTER XVIII.

MOLLUSCA PROPER.

CLASS VII.—CEPHALOPODA.

General Characters and Structure of Cephalopoda—Classification.

CLASS VII. *Cephalopoda.*—This class, the last and highest of the Molluscan sub-kingdom, is distinguished by the possession of a circle of arms, feet, or tentacles, borne on the head, and in the centre of which the mouth is situated. From this characteristic, the name *Cephalopodous* or "Head-footed" Molluscs has been derived, and a glance at the figure of an ordinary member of the group (Fig. 82, A, B) will show that the term has not been misapplied. The remaining special and distinctive features of the group are comprised in the following definition : body enclosed in a muscular mantle-sac ; respiration by two or four plume-like gills contained within the mantle ; the effete water of respiration being ejected by an anterior aperture, usually prolonged into a tube, and termed the "infundibulum," or "funnel" (Figs. 82, A, B, and 85, A.) In appearance the Cephalopoda are sufficiently remarkable to attract attention ; many of these forms, indeed, are exceedingly grotesque, and even uncouth, and serve in no ordinary manner to remind the observer of the monsters celebrated in fable and mythological lore. And when we lastly remark that the relations of the group, viewed morphologically, or with regard to their distributional aspects, are of the most exceptional kind, enough will have been said to indicate that the study of the Cephalopoda is in every respect calculated to excite both interest and admiration.

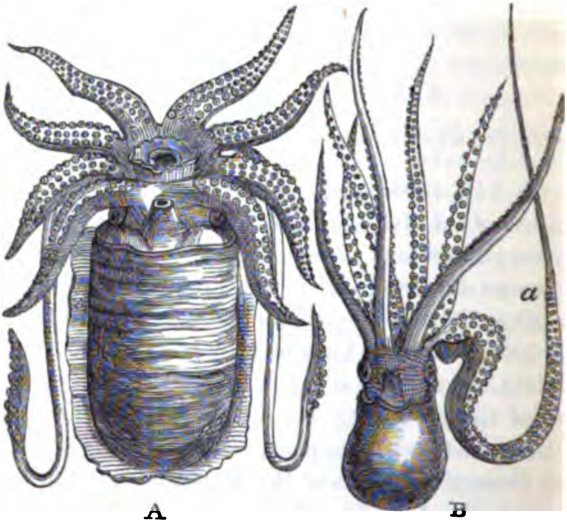


Fig. 82. DIBRANCHIATE CEPHALOPODA.

A, *Sepia officinalis*; a *Decapodous* Cephalopod (reduced), showing the mouth, arms, tentacles, and funnel. B, *Octopus carena* (male); an *Octopodous* Cephalopod, showing the funnel and the "hectocotylised" arm (*a*).

The external characteristics of the group demand attention in the first instance. The body in the majority of instances is more or less elongated, and is enclosed in a mantle-sac, endowed with a considerable degree of muscular power. Of living Cephalopods, only two possess distinct external shells, and of these, as will be presently noticed, only one—the Pearly Nautilus—is provided with a shell corresponding to that structure in other Mollusca: the so-called "shell" of the second and remaining form—the *Argonaut*, or Paper Nautilus—being properly regarded as a mere foot-secretion. The vast majority of existing Cephalopoda are therefore destitute of an external shell, their bodies being thus naked and comparatively unprotected. An internal "shell" (Fig. 83), however, exists in these latter forms, this structure being found enclosed in the mantle-sac by which it is secreted, and known from its shape and appearance as the "sepiostaire," "cuttle-bone," or "pen." This structure is further, in many cases, of the most rudimentary description, and its form and relations will be considered when treating of the "shell." The body in the Cephalopoda is equally developed on each side of the mesial plane; it is therefore bilaterally symmetrical. In the *Sepia*, which forms perhaps the most typical example of the group, the body is somewhat ovate in form, the mantle being expanded at the sides of the body to form a marginal fin (Fig. 82, A); whilst in the Common Squid, or Calamary (*Loligo vulgaris*), exemplifying a still more familiar species, the integument is extended laterally, at the posterior extremity of the body, two fins of triangular shape being thus formed. The integument in the Cephalopoda consists of a firm under layer, corresponding to the true skin, and of an upper transparent layer or "epidermis." Certain cells containing pigment of various colours are embedded in the under layer, or, as it has been termed, the "pigmental layer" of the skin, and to these cells the term "chromatophora" has been applied. By altering the position of these cells, and by thus bringing them into view through the transparent epidermis, or, on the other hand, depressing them into the deeper layer of the skin, these creatures can intensify the hues of their bodies, and otherwise change the colour of the skin; this chameleon-like propensity having long been observed in the Cephalopoda.

The "arms;" "feet," or "tentacles"—for each or all of these designations apply equally well to these appendages—may be considered next in order. These organs are formed by peculiar modifications of the "foot," the nature and relations of which have been examined in the previous classes of the Mollusca; the "infundibulum" or "funnel" also appears to be formed by the modification of part of this structure. The arms partake of the muscular power to a very great degree, and exist to the number of eight or ten in all living Cephalopods, save one—the Pearly Nautilus—in which these organs are numerous, and differ in certain important respects from those of the other forms. In the Decapodous Cephalopods (Fig. 82, A), in which ten arms exist, two of these appendages are greatly elongated, these latter being distinguished from the remaining and shorter "arms" by the name of "tentacles."

The function of the tentacles is probably that of serving to moor the animal to fixed objects, or for the capture of prey at a distance. The arms are provided on their inner surfaces with numerous "acetabula" or "suckers," which may be either sessile and attached directly to the "arm," or supported on distinct processes, when they are said to be "pedunculated." Each "sucker" consists essentially of a cup-shaped disc, bounded by a firm cartilaginous ring, and containing muscular fibres, which converge towards the centre of the disc, at which point an aperture of circular shape exists, and a small muscular eminence, or "papilla," being contained within this circular and central aperture. The mechanism, therefore, by which each sucker is made to adhere firmly to any surface to which it may be applied, will be readily understood. The "papilla" being retracted and depressed by the action of the radiating muscular fibres of the disc, a vacuum is produced, and the sucker is thus enabled to retain a firm hold of the surface; whilst to release its hold, the "papilla" or "piston" has merely to be pushed forwards, the vacuum being thus destroyed, and the otherwise firm grasp released. And when it is borne in mind that the suckers, in the majority of instances, are exceedingly numerous on each of the arms, and that the adhesive apparatus can be brought into play at once, and with the utmost readiness, and at all times, the tenacity and power of the Cephalopod's grasp will be readily appreciated and understood.

In addition to this comparatively simple structure above described, the suckers in several forms are provided with hooked processes or claws, this arrangement adding to the already perfect organisation of this part of the economy of these creatures. Whilst the entire inner surface of the ordinary "arms" is provided with sucking-discs, the expanded extremities only of the elongated "tentacles" are furnished with these appendages; this arrangement in the case of the "tentacles" being specially adapted for the functions, which, as previously noticed, they are intended to subserve.

Locomotion is effected in the Cephalopoda after two distinct fashions: firstly, by aid of the "arms," which thus possess a twofold function, combining the offices of prehensile and locomotive apparatus; and, secondly, by the expulsion of the effete respiratory water from the anterior "funnel" previously mentioned. In the first of these modes, by aid of the arms and their suckers, the Cephalopoda are enabled to walk head downwards at the bottom of the sea, and by aid of the expulsion from the "funnel" of the effete respiratory water, they can propel themselves backwards in the water. The fins with which the bodies of certain genera are furnished, constitute a third means by which locomotion may be effected, the triangular posterior fins in the Calamary aiding the creature in its lithe and active movements. The Cephalopoda thus progress by two modes of locomotion, which, in the case of most other and ordinary animals, would seem the most awkward that could possibly be suggested, but which, in the present instance, are of all others the most admirably suited to the respective wants and requirements of Cephalopod life.

The "shell" of the Cephalopoda may be either internal or external. As previously mentioned, it exists as an external shell in only two instances; and to these it may be convenient, in the first place, to direct attention. The most typical, and, indeed, the only true external "shell," is that possessed by the *Nautilus Pompilius*, or "Pearly Nautilus" (Fig. 86), a form to be carefully distinguished from the *Argonauta Argo*, or "Paper Nautilus" (Fig. 85, A), in which an external shell, but of widely different relations and structure from that of the Pearly Nautilus, also exists. The "shell," in the *Nautilus Pompilius*, is secreted by the mantle, and is therefore to be considered as truly homologous with the "shells" of other and ordinary Molluscs: it is thus a true secretion of the body to which it is organically connected. Very different in its relations is the so-called shell of the *Argonaut*, or "Paper Nautilus," which is secreted by two of the arms, these organs being expanded and otherwise developed for this purpose. The "shell," in this latter case, is therefore to be regarded as a mere "pedal" or "foot" secretion, between which and the body of the animal no intimate or organic connection exists. It may suffice, in the present instance, to notice further, that whilst the shell of the *Nautilus*, on the one hand, is thus a perfectly formed shell, the interior of which is divided into a number of chambers, by partitions, or "septa," as they are termed, that of the *Argonaut*, on the contrary, consists of but a single chamber, and appears to be principally used as a receptacle for the ova. The majority of existing Cephalopods, whilst destitute of an external shell of any kind, possess an internal shell which may vary in perfection throughout the group, and which is known as the "Sepiostaire," "cuttle-bone," or "pen" (gladius) (Fig. 83, *a*, *b*). Thus, in the Calamary, the "shell" exists as an elongated, pen-like structure (Fig. 83, *a*), composed of horny material, and

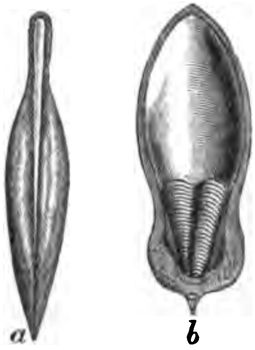


Fig. 83. INTERNAL SHELLS OF CEPHALOPODA.

a, Internal shell of the Calamary (*Loligo*), known as the "pen" or "gladius;" *b*, "Sepiostaire," or "bone" of the Cuttle-fish (*Sepia*).

enclosed in the middle line of the dorsal portion of the mantle; whilst, in the *Sepia*, the shell (Fig. 83, *b*), exhibits a higher degree of specialisation, and consists of an oval plate of calcareous or horny material, which shows an evident tendency, at its expanded and concave extremity, to become further developed, and to approach in structure to a type of shell to be noticed in the next instance. Between the two types of shell formed by the external "shell" of the *Nautilus*, and the rudimentary internal shell of the *Loligo* or *Sepia*, an intermediate form, serving to connect the two types in a graduated series, is interposed. This intermediate condition is found in the extinct group of the *Belemnitidæ* or *Belemnites*, the shells of which are found as characteristic fossils of the secondary formations of the world, and of which a restored figure of a typical example is depicted at Fig. 87, 1. The shell of the Belemnite, like that of the Sepia and its neighbours, was internal, but it exhibited a structure of much greater complexity, and of nearer affinity to the chambered shell of the *Nautilus* than that of any existing forms. The *Belemnitic* shell thus consisted of an anterior pen-like portion, the "pro-ostracum" (Fig. 87, 1, *e*) and of a posterior chambered portion, the "phragmocone" (*g*). The "phragmocone" was of conical shape, and was divided into chambers by a series of "septa" or partitions, traversed by a "sipuncle" or tube, which perforated them at their dorsal or superior margin (Fig. 87, S). The chambered "phragmocone" was lodged in a sheath termed the "alveolus," which in turn was contained within a more solid portion, known as the "guard" (Fig. 87, 1, *h*). The ink-sac of the Belemnite (Fig. 87, 1, *f*) is in some cases found preserved with the fossil "shell." This curious organ, to which allusion will presently be made, appears to have been contained within the last or basal chamber of the "phragmacone." Lastly, in the limited group of which the *Spirula* forms the sole representative, the internal shell is still further developed, and consists of a series of chambers, separated by septa, which are also perforated by a marginal tube or "sipuncle;" the shell in this latter instance approaches more nearly than that of the *Belemnitidæ* to the chambered shell of the Nautilus. The important generalisation thus adduced from the study of shells of both living and extinct Cephalopods, will be more fully comprehended when the classification and relations of the various divisions of the class are duly understood.

The mouth (Fig. 82, A) is situated in the centre of the superior aspect of the head, and is provided with a masticatory apparatus (Fig. 84, *b*), formed by two beak-like jaws or mandibles, of horny or calcareous consistence, which, by the aid of appropriate and powerful muscles, act in a vertical direction, and thus serve to break down the hard substances—such as the shells of Crustacea, etc.—upon which the Cephalopoda feed. In addition to these jaws an "odontophore" is also present, this organ, as in other Molluscs, consisting of a tongue, armed at its posterior extremity with spinous teeth, curved in a backward direction. Salivary glands (Fig. 84, *d*), of large size, are present, the ducts of these organs opening into the œsophagus, or gullet (*f*), which, after dilating in some species into a "crop," terminates in a distinct stomach (*h*). The intestine (*i*), its first flexure being neural, is continued in a more or less straight course to the anus (*k*), which opens at the base of the "infundibulum," or "funnel" (*l*). The liver (*p*) is large, and a rudimentary pancreas appears in some cases to be present. In connection with the digestive system, it may be well to notice the peculiar organ in Cephalopods to which the name of "ink-sac" (Fig. 84, *m*) is applied. This organ exists as a gland or sac of small size, situated in some few instances in close connection with the liver, whilst its position in other cases appears to vary greatly. The duct of the "ink-

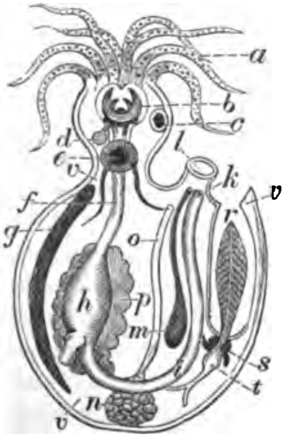


Fig. 84. Diagram of Cephalopod.

a, Tentacles; *b*, buccal or masticatory apparatus; *c*, eye; *d*, salivary gland; *e*, nervous ganglia, enclosed in a cartilaginous capsule, which also contains the auditory or hearing vesicles; *f*, œsophagus; *g*, internal shell, or "sepiostaire;" *h*, stomach; *i*, intestine; *k*, anus; *l*, funnel, or "infundibulum;" *m*, ink-sac, the duct of which terminates at base of funnel; *n*, ovary; *o*, oviduct; *p*, liver; *r*, gill, contained in branchial chamber; *s*, "branchial" heart; *t*, "systemic" heart; *v v v*, mantle.

sac" opens at the base of the "funnel" (*l*), in close proximity to the anal aperture. The obvious use of the secretion of the ink-sac is to serve as a means of defence, the Cuttle-fish, when hard pressed by its enemies, ejecting the inky fluid from the "funnel," and making its escape under the literal cloak of darkness produced by the rapid diffusion of the fluid through the surrounding water. The homologies of the peculiar organ have formed subject-matter for discussion for a very considerable period of time. By some authorities the ink-sac was considered, from its relation in certain forms to the liver, to be homologous with the gall-bladder of other forms: others have maintained its affinity to the urinary apparatus; whilst a third section advocate the idea of its being a special apparatus.

The circulatory system in the class under consideration presents certain interesting modifications of the ordinary Molluscan type, two distinct sets of circulatory organs being found. The venous blood returning from the body to be purified, is carried by the *venæ cavæ* or great terminal venous trunks, to contractile cavities, situated one at the base of each gill, and termed from their situation "branchial" or "gill" hearts (Fig. 84, *s*). The sole function of these "branchial hearts" is the propulsion of the blood into the respiratory organs, where it is purified, and returned as aërated blood to the true systemic heart (Fig. 84, *t*), which, consisting of but a single chamber, propels the blood in turn through the body. Functionally regarded, therefore, the heart of the Cephalopod is superior to that of other Mollusca, and exhibits a decided advance in this respect towards the perfection of the circulatory apparatus of the higher forms; the "branchial" or "venous" hearts corresponding in function, or being analogous to, the right or venous side of the heart in the bird or mammal. The *venæ cavæ*, or terminal veins, are intimately associated with certain bodies of a spongy or glandular consistence. These organs are supposed to subserve a renal function, and are therefore believed to be analogous with the urinary apparatus of the higher animals; their function in this respect being the elimination from the system of a certain proportion of the tissue-waste, which is excreted from the impure blood returned and conveyed by the great venous trunks with which these organs are connected.

The respiratory organs consist of two or four plume-shaped gills (*r*), situated on the sides of the body, and enclosed in a branchial or respiratory chamber, formed by a special arrangement of the mantle-sac. Each gill consists of a main stem, supporting alternate transverse "laminæ" or "plates," which in turn give origin to smaller plates, the surface over which the venous blood is exposed to the oxygen of the water being thus materially increased. Water is admitted to the branchiæ by the upper and anterior free edge of the mantle-sac, reflux of the fresh water being prevented by a valvular arrangement of the mantle, whilst the effete water is ejected by the "funnel," and regurgitation being similarly prevented in this latter instance. The mode in which the *jet d'eau* from the "funnel" is made subservient to the locomotion of the Cephalopoda has been already noticed.

The nervous system exhibits a high degree of concentration, and also shows an affinity to the disposition and arrangement of the cephalic or head ganglia in the vertebrate type, in that the chief nervous centres (Fig. 84, *e*), in the present instance, are enclosed in a cartilaginous capsule, representing a rudimentary cranium or skull. The senses are present in a high degree of perfection, the eyes being especially large, and so constructed as to enable the creature to see far and near in his subaqueous abode. The sense of hearing is subserved by two auditory vesicles (Fig. 84, *e*), containing a calcareous body or "otolith," suspended in a clear fluid, and supplied with filaments from the auditory nerves. The sense of taste is supposed to reside in the anterior soft portions of the "odontophore" or "tongue," and the olfactory sense has been conjectured to be exercised by the "lips," or external processes surrounding the mouth.

The sexes in the Cephalopoda exist in separate individuals, and the relations of the reproductive system in certain members of the group, exemplified by the ordinary Cuttle-fishes, exhibit certain features of peculiar and somewhat anomalous kind. The female reproductive organs consist of an ovary (Fig. 84, *n*), with its efferent tube or "oviduct" (*o*), opening into the pallial chamber, together with certain structures, the function of which is to produce a glutinous or viscid secretion, by means of which the ova or eggs are fastened together in masses. To these glands the term "nidamental" glands is applied, and the agglutinated masses of the eggs of these creatures present no inconsiderable resemblance to a bunch of grapes, the familiar name of "sea-grapes" being given to them on this account. The disposition of the male generative organs, however, exhibits certain remarkable features, one of the "arms" being modified to subserve the reproductive process. This modified "arm," known as the "hectocotylus" (Figs. 82, B, *a*, and 85, C, *a*), serves to convey the male element within the pallial chamber of the female, and thus to impregnate the ova. For this purpose the arm is, in many cases, detached and deposited within the pallial chamber of the female. The *Argonauta Argo*, or Paper Nautilus (Fig. 85), exemplifies this latter mode; whilst, in other genera, as in *Octopus* (Fig. 82, B), the "hectocotylised" member (*a*) remains attached to the male animal. The mode of development of this curious arm also varies throughout the group; typically it appears to be produced from a cyst-like structure, by the rupture of which the "hectocotylus" is liberated. In the majority of instances, this reproductive member, like the other and ordinary arms, is provided with suckers, the function of which, in the performance of the reproductive process, will be at once apparent.

As might be conjectured, the discovery of the singular series of phenomena above described tended to disprove the many speculations and theories which from time to time were indulged in respecting the reproductive function in the Cephalopoda, the Paper Nautilus being the form in which the relations of the generative system were first and correctly determined. The female *Argonaut*, possessing the "pedal shell," had long been described; but nothing definite regarding the male animal was known until the "hectocotylus" was found as a detached organism attached to the female. The reproductive member was accordingly first described as a parasitic worm, and subsequently as the male Argonaut itself, until, in the *Octopus carena* (Fig. 82, B), a member of the family *Octopodidæ*, a similar and "hectocotylised" arm was found developed, in place of one of the ordinary members of the animal, this discovery at once suggesting the analogy between the detached "hectocotylus" of the *Argonaut* and the attached reproductive arm of the *Octopus*. The discovery of the male *Argonaut* itself, at a still later period, gave the desired opportunity of verifying the preceding observations. Lastly, in the subsequent development of the Cephalopod ovum, and in the various stages through which the embryo advances to its final evolution as the perfect form, certain features, widely different from the similar phases of development in other Mollusca, are observed; the special and peculiar characters of the Cephalopodous structure being discernible at a very early stage in the process of development, and the usual and transitory stages seen in other and lower forms being wholly wanting in the present instance.

In habits the Cephalopoda are carnivorous, feeding upon Crustacea and allied forms, and also upon fishes, which they succeed in capturing by means of their efficient prehensile apparatus.

Stories of gigantic members of this group are plentifully met with, especially in the traditional records of the older navigators, and for these, as a matter of course, a considerable latitude, amounting in most instances to disbelief, must be allowed. Still, several well-authenticated instances are on record in which Cuttle-fishes of large, or even enormous size, have been met with; but these, it is needless to say, do not at all approach to the reputed bulk of the ordinary tales with which the navigators of bygone days, and indeed some of more recent times, thought fit to entertain a credulous auditory.

CLASSIFICATION.—The *Cephalopoda* are divided into two orders, which are distinguished primarily by the number of gills. The order *Dibranchiata*, in which, as implied by the term, two gills exist, includes all living Cephalopoda, with one exception—that of the Pearly Nautilus (*Nautilus Pompilius*)—in which four gills exist, and which therefore forms the sole representative of the *Tetrabranchiata*, the second and remaining subdivision of the class.

The other and minor characteristics which separate these two orders are found in, firstly, the number and nature of the "arms," which never exceed ten in number in the *Dibranchiata*, in which group they are provided with suckers: in the *Tetrabranchiata* the arms are numerous and are destitute of suckers. The second point of distinction consists in the presence or absence of an ink-sac, that structure being present in the former but wanting in the latter group. Thirdly, the "funnel" exists as a complete tube in *Dibranchiate* Cephalopods, whilst in the *Tetrabranchiata* the funnel does not form an entire tube. Lastly, the shell in Dibranchiates is for the most part internal and rudimentary, or, if external, it is not divided into chambers: in the Tetrabranchiata, on the contrary, the shell is external—chambered; the "septa," or partitions, being perforated by a tube termed the "sipuncle."

Order 1. *Dibranchiata.*—In the *Dibranchiate* order, two sections, distinguished by the number of the arms, are recognisable; the *Octopoda*, forming the first section, possessing eight, whilst the *Decapoda* possess ten arms, two of these ten appendages being elongated to form "tentacles." The suckers in the *Octopoda* are sessile, whilst those of the *Decapodous* "arms" are pedunculated, or supported on short stalks.

The *Octopoda* are represented by two families:—(*a*) *Octopodidæ* and (*b*) *Argonautidæ*. The *Octopi* or *Poulpes*, of which an example is depicted at B, Fig. 82, represents the first of these families; whilst the *Argonauta Argo*, or Paper Nautilus (Fig. 85), forms the sole example of the second group. The female (Fig. 85, A, B), as previously mentioned, is most frequently met with, and she alone possesses an external shell, of extreme delicacy of texture, and from the possession of which the familiar name of "Paper Nautilus" is derived. Two of the arms ("dorsal arms ") are expanded at their extremities, so as to form webbed or membranous discs (Fig. 85, B), and upon these devolves the function of secreting the "shell," and of repairing it when injured. The shell being thus secreted by these "arms," and being thus truly a "pedal shell," bears no homological relation to the "shell" of other Molluscs, or to that of the *Nautilus*, which is

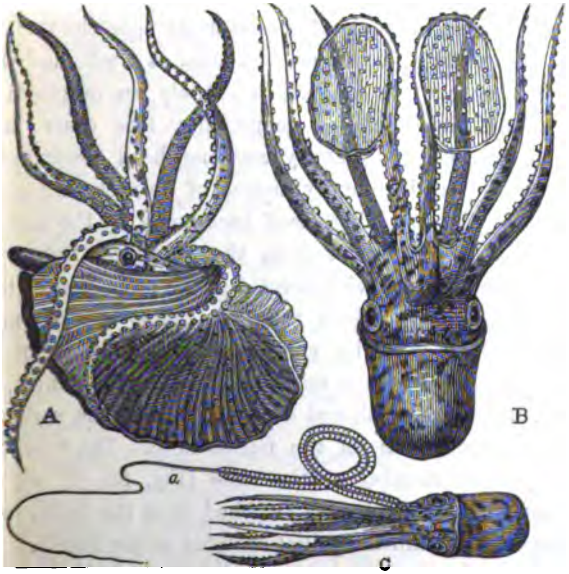


Fig. 85. DIBRANCHIATE CEPHALOPODA.

A, Paper Nautilus (*Argonauta Argo*), showing the funnel and webbed arms clasping the shell. B, The *Argonaut* removed from the shell, and showing the webbed arms. C, Male Argonaut, showing the "hecto cotylus" (*a*).

secreted as in ordinary cases by the "mantle" of the animal. The "shell" of the *Argonaut* is not chambered, and it is further not organically connected to the body of the animal. Its chief use appears to be that of serving as a receptacle for the ova. The popular and poetic notion that the *Argonaut* floats upon the surface of the water, using its webbed arms as a sail, and the other appendages as oars, is entirely an imaginative fiction; the *Argonaut* progressing, like other and mundane Cuttle-fishes, by crawling, head downwards, over the sea-bottom, by means of its acetabuliferous arms, or by propelling itself backwards, by the action of the jets of water from the anterior "funnel;" the webbed arms being devoted to the protection of the "shell," against which they are closely applied, and which they generally embrace. The male *Argonaut* (Fig. 85, C), which is much smaller than the female, is destitute of a shell, and does not possess the webbed arms characteristic of the female form. The "hectocotylised" member of the male (Fig. 85, C, *a*), as previously mentioned, is detached from the body, and deposited within the pallial chamber of the female.

The *Decapoda*, forming the remaining section of the *Dibranchiata*, are represented by four families, the last of which, represented by the *Belemnites*, includes only extinct forms. The (*a*) family, *Teuthidæ*, is represented by the Calamaries, or Squids, which constitute the most familiar of our British Cephalopods, these forms being cast upon our shores in great numbers after a storm. The body, in the *Teuthidæ*, is elongated, and provided with two lateral and posterior fins. The (*b*) *Sepiadæ* are represented by the *Sepia officinalis* (Fig. 82, A), the typical Cuttle-fish. The body is more or less ovate in form, and furnished with a marginal fin. In the (*c*) *Spirulidæ*, the internal shell, previously alluded to, exists as a chambered structure, and resembles in shape the shell of the Tetrabranchiate *Nautilus*, the "septa," or partitions of the shell being perforated by a marginal sipuncle. The (*d*) *Belemnitidæ* (Fig. 87, 1), forming the last family included in the Decapodous section, and also in the Dibranchiate group, serve to unite the rudimentary shell of the Dibranchiata generally with the more perfect organisation of the Tetrabranchiate shell. The Belemnites are known to us only from their fossil remains, and from an inspection of the characteristics thus presented to us, we are enabled to determine that the Belemnites are nearly allied to the existing *Sepiadæ*. The essential structure of the internal shell, and its relations to the shells of the other members of the order, have been already discussed.

Order 2. *Tetrabranchiata.*—The *Nautilus Pompilius* (Fig. 86), familiarly known as the "Pearly Nautilus," is the only living representative of this group, which, however, is abundantly exemplified by extinct and fossil forms. Our knowledge of the *Nautilus* is derived from the examination of a single perfect specimen, dissected by Professor Owen, and in which the chief and distinctive structural points were fully determined.

The shell is of spiral form, the whorls being contained in one and the same plane, and it is further divided by a series of "septa," or partitions (Fig. 86, *g*), into numerous chambers, the last formed and largest of which (*e*) serves to contain the body of the full-grown animal. Each chamber was in turn inhabited by the *Nautilus*, but as it retired from each chamber on account of its increasing growth, it built up or secreted between its body and the evacuated chamber a vertical wall, or "septum" (*g*). Communication between the various chambers of the shell and the body of the animal is kept up by means of a tube or "sipuncle" (*s s*), which, in the case of the *Nautilus*, passes through the middle of each "septum" (*g*). The sipuncle ter-

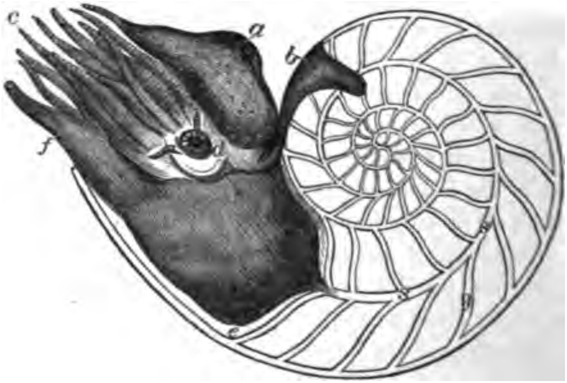


Fig. 86. TETRABRANCHIATA.

The "Pearly Nautilus" (*Nautilus Pompilius*), with the shell in section, and showing, *a*, upper fold of mantle or "hood"; *b*, dorsal fold of mantle; c, tentacles; *d*, eye; *e*, last or "body," chamber of the shell; *f*, funnel; *g*, septum; *s s*, sipuncle.

minates anteriorly in the "pericardium," or investing sac of the heart, its function and relations being as yet unknown. The entire structure of the shell, however, renders the conjecture that it may be used as a hydrostatic apparatus at least probable. In conformity with this theory, the animal is supposed to possess the power of filling the chambers with some gas, and by thus reducing the specific gravity of its body, enabling it to rise in the water. The head is surrounded by numerous arms or tentacles (*c*), destitute of suckers, and, from their structure, evidently designed to subserve the tactile sense in a very perfect manner. Locomotion is effected by the forcible expulsion of the effete respiratory water from the "funnel" (*f*).

The Tetrabranchiata include two families (*a*) *Nautilidæ* and (*b*) *Ammonitidæ*, each of which divisions includes a large number of extinct genera. The structure and relations of the *Nautilus* to its shell being comprehended, the relations of the extinct members of the group will also be readily perceived. In the Nautilus the "septa," or partitions of the shell (*g g*), are simple, their margins being entire; whilst the sipuncle (*s*) perforates the "septa" at their centres. The extinct forms included with the existing *Nautilus*, in the family *Nautilidæ*, agree with that form in the plain and entire character of the septa, the position of the sipuncle, however, varying throughout the group. The *Orthoceras* (Fig. 87, 3) represents the most familiar type of extinct shells included in the Nautilus family. In this form the shell was more or less straight, a type of structure we might suppose to be imitated by uncoiling the spiral shell of the Nautilus to form a straight and elongated shell. The typical position of the sipuncle in *Orthoceras* (Fig. 87, 3, *a*) is in the centre of the septa; but in certain cases it is marginal in position, and its structure appears to have been of somewhat complicated nature.

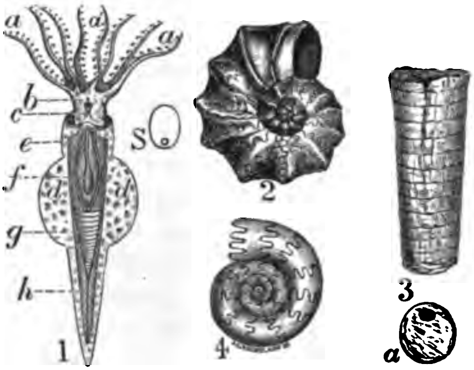


Fig. 87. PALÆONTOLOGY OF CEPHALOPODA (after Owen).

1. Diagram of restored *Belemnite*: *a a a*, acetabuliferous arms; *b*, head; c, funnel; *d d*, lateral fins; *e*, "Pen" or "Pro-ostracum;" *f*, ink-sac; *g*, chambered "Phragmocone;" *h*, "guard;" S, septum, from "Phragmocone" of *Belemnite*, showing the marginal sipuncle. 2. *Ceratites nodosus* (Muschelkalk), an extinct Tetrabranchiate Cephalopod, showing the "sutures." 3. *Orthoceras laterale*, showing the septa; *a*, septum of *Orthoceras*, showing the marginal sipuncle. 4. *Goniatites Henslowi* (Carboniferous), showing the "sutures."

In the (*b*) *Ammonitidæ*; on the other hand, of which the *Ceratites nodosus*, depicted at 2, Fig. 87, and the *Goniatites Henslowi* (Fig. 87, 4) may be selected as familiar representatives, many extinct and highly characteristic forms are included. The *Ammonites* themselves form the typical genus, and of these forms the Nautilus may be considered the existing prototype. The special and distinctive features of the *Ammonitidæ* consist, firstly, in the complex character of the septa, these partitions being serrated and indented to a greater or less degree (Fig. 87, 2). The edges or margins of the septa, represented on the external surfaces of the shells, are known as "sutures" (Fig. 87), and exhibit a highly ornate and beautiful appearance. The position of the sipuncle in the *Ammonitidæ* forms a second feature in the distinction of the group, that tube perforating the septa at their external or convex margins. Besides the forms above mentioned, the *Baculites, Turrilites, Scaphites, Ancyloceras,* and many other examples, illustrate the special characteristics of the group.

Fossil Cephalopoda of the Tetrabranchiate order made their appearance at an early period of the earth's history; and, from their frequent and general occurrence throughout the rock-systems of the various epochs, there is every reason to believe that the Tetrabranchiata held a position in the ancient life-series similar to that now occupied by the Dibranchiate forms, which latter attain the maximum of their development in the present day.

Classification of Mollusca.

Sub-kingdom Mollusca.

Division A. Molluscoida.

- Class I. Polyzoa
  - Order (a) *Phylactolæmata*. Ex. Cristatella.
  - Order (b) *Gymnolæmata*. Ex. Flustra.
- Class II. Tunicata. Ex. Ascidia.
- Class III. Brachiopoda. Ex. Terebratula.

Division B. Mollusca Proper.

- Class IV. Lamellibranchiata
  - Order (a) *Asiphonida*. Ex. Ostræa.
  - Order (b) *Siphonida*. Ex. Mya.
- Class V. Gasteropoda
  - Sub-Class A. Branchifera.
    - Order (a) *Prosobranchiata*. Ex. Buccinum.
    - Order (b) *Opisthobranchiata*. Ex. Doris.
    - Order (c) *Nucleobranchiata*. Ex. Carinaria.
  - Sub-Class B. Pulmonifera.
    - Section (a) *Inoperculata*. Ex. Helix.
    - Section (b) *Operculata*. Ex. Cyclostoma.

CLASS VI. PTEROPODA	Order (a) *Thecosomata.* Ex. Hyalæa. Order (b) *Gymnosomata.* Ex. Clio.
CLASS VII. CEPHALOPODA.	Order (a) *Dibranchiata.* Section (1) *Octopoda.* Ex. Octopus. Section (2) *Decapoda.* Ex. Sepia. Order (b) *Tetrabranchiata.* Ex. Nautilus.

CHAPTER XIX.

VERTEBRATA.

General Characters, Morphology, and Physiology of Vertebrata—Classification.

In entering upon the consideration of the last and highest type of animal structure, we find the forms included within that type bound closely together by several very definite characters, and forming thus a section more distinct than any of the preceding divisions. Throughout the Invertebrate Series each subkingdom possessed undeniable relations with the other groups; certain forms exhibiting transitionary features, and thus serving to connect each type more or less insensibly with its neighbours. But with the Vertebrata the case is somewhat altered, and the relations of this higher group would appear to be more distinctly specialised, and its boundaries to be better defined and more marked, than those which existed between the types included in the Invertebrate Series.

The most distinctive and characteristic of the features by which the Vertebrata are distinguished from all Invertebrate animals, consists in the specialisation of the chief nervous centres, and in their peculiar relation to the other systems of the body. These relations will be readily understood from the accompanying diagrams, representing transverse sections of the body of an Invertebrate and of a Vertebrate animal respectively. Thus in the Invertebrate (Fig. 88, A), the body is represented by a single and simple tube, containing the various systems and organs. At *p* (Fig. 88, A), the parietes or walls of the body are represented; at *n*, the nervous system; the blood or hæmal system at *h*; whilst the alimentary canal occupies an intermediate position as depicted at *a*. This diagram therefore represents the essential and typical relation of parts in an Invertebrate animal—such as a Worm—and the distinctive feature to be at present noticed consists in the disposition and relation of the nervous centres, which are accordingly seen to be contained in the same

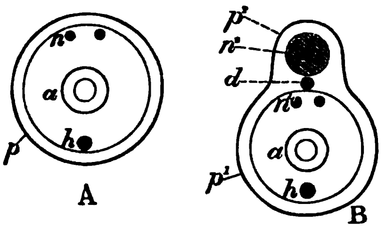


Fig. 88. COMPARATIVE MORPHOLOGY OF VERTEBRATA AND INVERTEBRATA (after Huxley).

A, Diagrammatic transverse section of Invertebrate; *a*, alimentary system; *h*, hæmal or blood-vascular system; *n*, neural or nervous system; *p*, parietes or walls of the body. B. Similar section of a Vertebrate animal; *a*, alimentary system; *d*, notochord; *h*, hæmal system: n^1, sympathetic, or ganglionic nervous system; n^2, cerebro-spinal nervous system; p^1, parietes of body; p^2, parietes or walls of the neural or nervous canal.

tube or body cavity (general or "somatic" cavity) with the other viscera. In other words, the body of an Invertebrate thus represented, is merely a "visceral" tube, and the nervous centres are not in any way partitioned or shut off from the other systems. Turning now to a similar diagrammatic section of a Vertebrate animal (Fig. 88, B), a widely different arrangement is at once perceived, and two distinct tubes are now viewed in place of the single tube of the Invertebrate section. In the upper or "dorsal" tube are contained the great centres of the "cerebro-spinal" nervous axis, (n^2), consisting of the brain and spinal cord, whilst the lower or "ventral" tube, is devoted to the reception of the alimentary (*a*) and blood systems (*h*), and generally also contains a series of nervous ganglia, representing the "sympathetic" or "ganglionic" nervous system, (n^1), and to which reference will be more fully made hereafter. The dorsal tube is therefore appropriately termed the "neural" tube, whilst to the lower and ventral tube the name "visceral" is applied. And on comparing these two sections, several important and obvious generalisations will at once be apparent. Firstly, that the upper or "neural" tube of the Vertebrate is entirely unrepresented in the Invertebrate; and, secondly, that the lower or "visceral" tube of the Vertebrate animal exactly corresponds to the single tube of the Invertebrate form; the contained organs of the Vertebrate "visceral" tube being homologous with those contained in the Invertebrate tube.

Viewed from a developmental aspect, the important character of these respective relations is more fully attested. In the development of the Vertebrate form, this specialisation of the nervous centres is observable at a very early stage of the process. The upper part of the embryonic surface becomes elevated on each side of the middle line into two parallel ridges, a groove, known to embryologists as the "primitive groove," being thus formed. Gradually, the margins of these ridges meet and unite in the middle line, to form by their union a second and dorsal tube, in which the "cerebro-spinal" nervous system (Fig. 88, B, n^2), is developed. The observation of this important feature affords an eminently clear illustration of the law of development propounded by Von Baër, and previously alluded to when treating of Protozoic development. The development here is "from the general to the special;" the characteristic features of the Vertebrate embryo being, at this early period in its history, clearly and distinctly perceptible. In the Invertebrate, on the other hand, these characteristic phases of development are wanting; no such specialisation of the nervous centres, and consequent division of the body, ever taking place.

The second distinctive feature of the Vertebrata consists in the presence, in the early embryonic life of every Vertebrate, of a soft gelatinous structure known as the "notochord," or "chorda dorsalis" (Fig. 88, B, *d*) which, as its name implies, exists in the dorsal region of the embryo. This "notochord" is formed in the floor of the "primitive groove" previously mentioned, and is to be regarded in the majority of cases as an embryonic structure, being replaced in the adult by the true "Vertebral column" or "backbone," and of which, indeed, the "notochord" is the early representative. In some instances, however, and most notably in the case of the *Amphioxus* or Lancelet, a fish exhibiting a very low type of organisation, the usual development of the "notochord" does not take place, that structure persisting in its embryonic condition throughout the life of the animal.

Thirdly, the "visceral clefts" or "arches," a series of openings situated at the sides of the mouth of the embryo, and by means of which that cavity is placed in communication with the external medium, are also characteristic solely of Vertebrate development. These clefts, as development proceeds, in the case of Fishes and certain Amphibians, bear the respiratory or breathing organs; whilst in the case of the higher animals they become entirely obliterated. Their persistence, however, in all Vertebrates as embryonic structures, constitutes another and characteristic feature of the group.

Fourthly, the limbs of Vertebrates are in no case more than four in number, but these, as in the case of Snakes, may be altogether absent; whilst a single pair of limbs only, as in the case of the Whales, may be developed. The limbs are articulated to the body, and are distinguished from the Invertebrate limbs by possessing an internal bony axis or "skeleton," to which the muscles moving the limb are attached.

Lastly, the jaws in Vertebrates are invariably parts of the head, and thus differ entirely from the jaws of Invertebrates, which, as in the case of the *Crustacea*, consist of modified limbs, or sometimes of hard developments in the mucous or lining membrane of the digestive tract. The so-called "gastric teeth" of many Crustacea and Insects exemplify this latter modification. Other and minor characteristics of the Vertebrata, consisting of peculiarities in the digestive, absorptive, circulatory, and nervous systems, will be more appropriately considered when treating of the various and general functions of the Vertebrata.

The general morphology of the Vertebrata may be systematically considered under the following heads:— 1. The Skeleton; 2. The Digestive system; 3. The Hæmal or Blood-Vascular system; 4. The Respiratory system; and 5. The Nervous system. Within the limits of a work like the present, and more especially of an elementary treatise on Zoology, it would be impossible to give any other than the briefest possible notice of the general morphology and physiology of the Vertebrata. The great physiological processes, seen to perfection in the Mammalia, will accordingly be described as they occur in that group of animals, the more characteristic and special features in the structure and physiology of the several groups, being noticed in the detailed description of the great divisions of the Vertebrate Series.

I. *The Vertebrate Skeleton.*—The hard parts of Vertebrates, like the similar structures in the Invertebrate Series, admit of a natural classification, into those borne on the surface or exterior of the body, and those situated internally. To the external hard structures the general term "exoskeleton" is applied, whilst the name "endoskeleton" is given to the internal framework or true skeleton, which, in the case of the Vertebrata, constitutes so characteristic a feature in their organisation. The parts of the "endoskeleton" also fall into a natural order, and are accordingly classed as those belonging to the head and trunk,—the "axial" elements—and those composing the limbs; these latter being in contradistinction termed "appendicular" elements.

So far as the intimate structure of the endoskeleton is concerned, a variety of textures, corresponding to various degrees of perfection in the development of the structure, are seen to enter into its composition. Thus, the simple fibrous "notochord" of the Lancelet (*Amphioxus*), (Fig. 101 A, *n*), represents the most primitive condition of the endoskeleton with which we are acquainted; the Sharks, Rays, and allied forms, introduce us to a more advanced condition of the structure, the endoskeleton in these cases being typically composed of cartilage, and in some instances exhibiting but little advance on the condition of the Lancelet; whilst, in the true bony fishes—exemplified by nearly all the ordinary members of that class—the endoskeleton consists of true bony material. And with the diversity in composition, variations in the degree of perfection to which a particular texture may be developed are also to be perceived. Thus in Fishes, the osseous material of the endoskeleton differs considerably in composition from that found in the skeleton of Birds; and, similarly, differences are also to be perceived in the intimate structure of the bony material of the Bird's skeleton, when we compare it with that of the Mammal.

The elements constituting the "axial" portion of the endoskeleton admit of being divided into two portions—the "spinal" elements, or those entering into the composition of the vertebral column, and the "cranial" elements, or those which constitute the skull. The "spinal" portion of the endoskeleton, together with the "cranial" portion, is made up of a series of segments to which the term "Vertebræ" is applied. These are seen to fullest perfection in the "vertebral column," "spine," or "backbone" (Fig. 91), which is thus composed of a series of "vertebræ," united together so as to form an axis of considerable strength, and further suited to support and form a basis for the attachment of the other portions of the endoskeleton. These "vertebræ" or segments are eminently homologous, and each consists typically of the following parts: (a) a more or less solid central piece, termed the "centrum" or body, (Fig. 89, A, B, C, *c*), from which the following processes take their origin; (b) two superior processes, the "neural arches" or "neurapophyses," (Fig. 89, *b b*), springing from the upper part of the "centrum," and uniting in the middle line to form a canal, termed, from its serving to protect the spinal cord (Fig. 89 A, *n*), the "neural canal;" (c) a superior spine, the prolongation of the "neural arches," and termed accordingly the "neural spine" (Fig. 89, *a*); (d) two inferior processes springing from the inferior aspect of the "centrum," and termed the "hæmal arches" or "hæmapophyses" (Fig. 89, *e e*), from their serving to protect the centres of the "hæmal" or blood-vascular system (Fig. 89, A, *o*), these latter processes being the exact prototypes of the "neural arches;" (e) an inferior or "hæmal" spine (*f*) formed similarly to the "neural" spine, by the prolongation downwards of the "hæmal arches;" (f), two "pleurapophyses" or ribs (*d d*), springing, one from each side of the "centrum;" (g), four articular processes, or

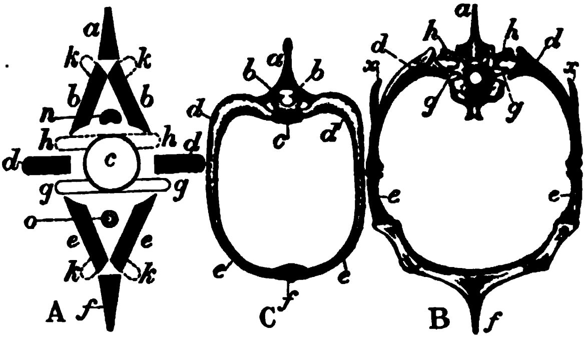


Fig. 89. Homology of the Vertebral Column. (After Owen.)

A, Ideal typical vertebra; *a*, "neural" or superior spine; *b b*, neurapophyses, or "neural arches;" *c*, centrum; *d d*, pleurapophyses; *e e*, hæmapophyses, or "hæmal arches;" *f*, hæmal spine; *g g*, parapophyses; *h h*, diapophyses; *k k k k*, zygapophyses; *n*, nervous centre; *o*, blood or hæmal centre.

B, Thoracic vertebra of Bird (*Vultur*); (the letters refer to similar parts in this and in the remaining figure): *x x*, diverging appendages fixing the ribs (*d d*) to each other.

C, Thoracic vertebra of Mammal. (References as above.)

"zygapophyses" (*k k k k*), for the attachment of the vertebræ to the neighbouring segments, borne, two by the "neural" and two by the "hæmal" arches; (h), two upper or superior "transverse processes" termed "diapophyses" (*h h*); and (i) two lower or inferior "transverse processes" termed "parapophyses" (*g g*), serving for the attachment of muscles, and springing from the base of the "neural" and "hæmal" arches. These various elements enter into the composition of a typical vertebra, but it must at the same time be borne in mind that only in certain cases are all these parts to be distinguished. And the study of comparative homology has received no greater stimulus than that given by Professor Owen, who, extending and perfecting the idea of Lorenz Oken, has at last, and by means of the construction of an "ideal typical vertebra," demonstrated the homology and unity of type of the vertebrate skeleton. This idea, at length clearly demonstrated, seeks to reconcile to this typical plan of structure the entire "axial" elements of the skeleton. The accompanying illustrations will serve to render these important generalisations sufficiently plain. Thus in the caudal vertebræ of the Crocodile (Fig. 90, B), the more important elements of the vertebra are at once recognisable, and will be readily referred to the typical parts of the "ideal" vertebra.

At *c*, the "centrum" or "body" is seen; the "neural arch" formed by the "neurapophyses" (*b b*), at *n*; the neural spine at *a*; the superior "zygapophyses" serving to articulate the vertebra to the neighbouring segments at *k k*; the short abortive "ribs" or pleurapophyses" at *d d*; the upper transverse processes or "diapophyses" at *h h*; whilst the "hæmal arches," formed by the "hæmapophyses" (*e e*), and the "hæmal spine" (*f*), are also to be observed. This, therefore, exhibits the various vertebral elements to a great degree of perfection; the lower "zygapophyses" or inferior "articulating processes," and the inferior "transverse processes, or "parapophyses" being alone suppressed. In the Bird (Fig. 89, B), the arrangement is also viewed in tolerable completeness, but with a certain degree of modification also. In this case the "hæmal arches" become largely developed, to form collectively the chest of the Bird; the ribs and "sternum" or "breast-bone," viewed after a homological aspect, forming definite parts of the typical vertebra thus constructed. As before, at (*c*), the "centrum" is seen,

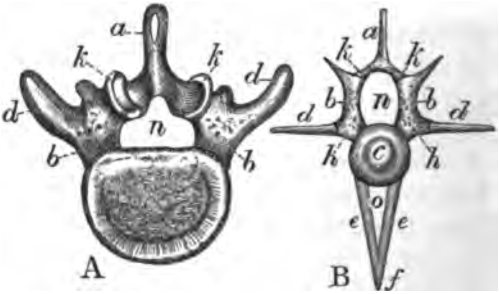


Fig. 90. Homology of Vertebral Column.

A, Lumbar vertebra of Man (references as in previous figure); *n*, neura canal. B, Caudal or Tail vertebra of Crocodile.

bearing the "neural arches" and "neural spine" (*a*), the "pleurapophyses" or ribs" (*d d*) are largely developed, and the "hæmapophyses" (*e e*) are short and articulated to the extremities of the ribs; whilst, lastly, the "hæmal spine" (*f*) is represented by the "sternum" or breast-bone, which in Birds of flight bears a strong bony ridge or keel, to which the muscles moving the wings are attached. And, similarly, in the complete and typical thoracic vertebra of a Mammal, such as Man, we find the "centrum" (*c*), "neural arches" (*b b*), and "neural spine" (*a*), as before; the upper transverse processes or "diapophyses" serving partly to fix the ribs, or "pleurapophyses" (*d d*); the "hæmal arches" or "hæmapophyses (*e e*) represented by the costal or rib-cartilages, and the "hæmal spine (*f*) by the "sternum" or "breast-bone." In both of these, as well as in the foregoing examples, the relations of the lower tube of the Vertebrate section (Fig. 88, B), with the upper or neural tube, will be readily perceived. The "cranial" portion of the endoskeleton also, it must be noticed, when· viewed from this aspect, is seen to be in like manner composed of a series of vertebræ or segments, peculiarly modified and adapted to form the bony case or "skull" for the protection of the brain.

A due appreciation of the homological value of this important subject being formed, no difficulty will be felt in properly understanding the generalisations therefrom deduced.

In the higher Vertebrate forms the vertebral segments exhibit great modifications of the typical plan.

Thus, in the lumbar vertebra of the human subject, figured at Fig. 90, A, the body (*c*), "neural arches," (*b b*), and "neural spine" (*a*), are at once observed; the "hæmal arches" and "hæmal spine" being deficient.

Turning now from these more transcendental considerations, the general morphology of the spinal column remains to be observed. The vertebral column is divided into five distinct parts, corresponding to as many defined regions of the body. The most anterior of these regions is the "cervical" or "neck" (Fig. 91, *b*) region, the vertebræ of which support the "cranium" or "skull" (*a*); the second, or "dorsal" region" (*d*), is that of the "back," the segments of this region bearing the ribs (*h*); thirdly, the "lumbar" region (*e*) or that of the "loins;" fourthly, the "sacral" region (*f*), constituted by a number of vertebræ, generally more or less firmly ossified together, so as to form an apparently single bone,—the "sacrum," which is wedged in between the two sides of the "pelvic" or "haunch bones" (*r*); fifthly and lastly, the "caudal" region (*g*), composed of a variable number of small vertebræ, and constituting the "tail" of the animal. Viewed as a whole, the vertebral column serves the twofold purpose of acting as a basis for the attachment of the other parts of the skeleton, and, together with the skull, forming a continuous canal (the "neural canal"), for the reception and protection of the great centres of the "cerebro-spinal" nervous axis.

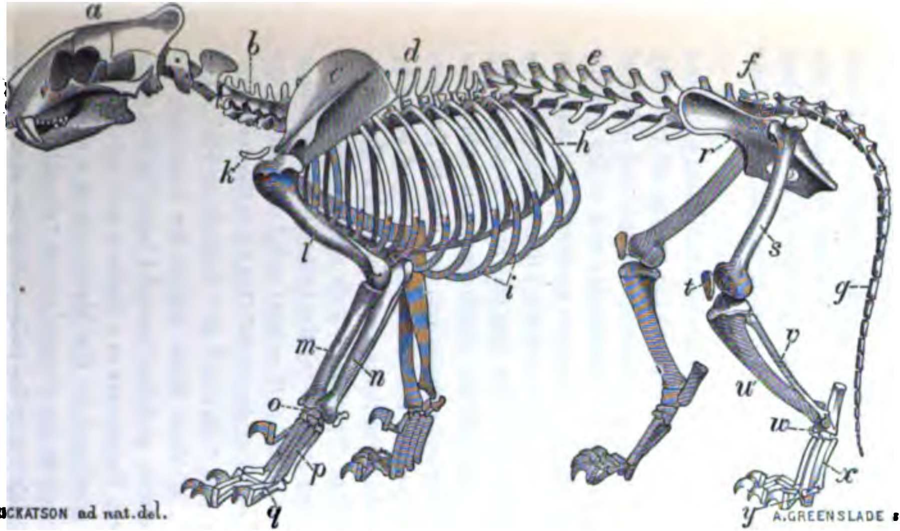


Fig. 91. OSTEOLOGY OF MAMMALIA. Skeleton of Tiger (*Felis Tigris*).

a, Skull ; *b*, cervical vertebræ ; *c*, scapula ; *d*, dorsal vertebræ ; *e*, lumbar vertebræ ; *f*, sacrum, composed of sacral vertebræ ; *g*, caudal vertebræ ; *h*, ribs ; *i*, costal cartilages attaching ribs to sternum or breast-bone ; *k*, clavicle, usually absent in *Carnivora*, but sometimes rudimentary, as represented in the figure ; *l*, humerus ; *m*, radius ; *n*, ulna ; *o*, bones of carpus or wrist ; *p*, metacarpus ; *q*, phalanges or digits (fingers) ; *r*, pelvis ; *s*, femur ; *t*, patella or knee-cap ; *u*, tibia ; *v*. fibula ; *w*, bones of tarsus ; *x*, metatarsus ; *y*, phalanges or digits (toes).

The morphology of the skull need not, on account of its complicated nature, be here entered upon. The more important modifications of the cranium, and those especially which refer to the form and relations of the lower jaw, will be more appropriately noticed when treating of the special morphology of the various subordinate groups.

The limbs of Vertebrates, whilst exhibiting a striking unity of structure throughout the group, are variously modified to suit the special requirements and habits of the respective classes of animals; and in the present instance, the typical structure, as observed in the limbs of the higher members of the sub-kingdom, may be briefly referred to. The fore and hind limbs, it may be noticed, are strictly homologous, and exhibit the same structure and composition, not only in the parts of the limb proper, but also in the series of bones by means of which the limbs are articulated to the trunk. The "fore" or "pectoral" limb consists typically of the following parts :—(a) the bones of the "shoulder-girdle," "scapular" or "pectoral arch," consisting of the "scapula" or "shoulder-blade" (Fig.91, *c*), the "coracoid" bone, and the "clavicle" or "collar-bone (*k*)." The scapula is, of these three bones, the most constant and important; and the "coracoid bone," whilst existing in most Vertebrates as a distinct and independent bone, is developed in the Mammalia as a mere process attached to the "scapula" or "shoulder-blade." The "clavicle" may be rudimentary in structure, or may be altogether wanting; (b) the "humerus" (*l*), or bone of the upper arm, which articulates with the "scapular arch" superiorly, and inferiorly with (c) the two bones of the forearm, named respectively the "radius" (*m*) and "ulna" (*n*), the former of which principally bears the hand, and serves to rotate the limb, whilst the latter acts chiefly in affording a point of fixation for the movements of the arm; (d) the "carpus" or "wrist" (*o*), formed by a variable number of small bones, and succeeded by the bones of the palm, technically and collectively known as the (e) "metacarpus" (*p*); to these succeed the (f) "phalanges" or bones of the fingers (*q*), and which number usually three to each digit.

The homology of the "pelvic" or hind limbs with the "pectoral" or fore limbs, will readily be distinguished, since we find, firstly, (a) the "pelvic arch" (*r*) supporting the hinder limbs, and corresponding to the "scapular arch" in the previous instance. The sides of the pelvis are formed by the two "innominate" bones, which, however, in early life, consist each of three distinct bones, and to each "innominate bone" the (b) "femur" or thigh-bone (*s*) is articulated. (c) The leg is formed by two bones, respectively termed the "tibia" (*u*) and "fibula" (*v*); whilst the (d) "tarsus" or bones of the ankle (*w*), (e) the "metatarsus" (*x*), and (f) "phalanges" or digits of the toes (*y*), correspond respectively to the wrist, palm, and fingers of the fore-limb.

II. *The Digestive System.*—The mouth (Fig. 92 *a*), in the majority of Vertebrates is provided with teeth, these organs, however, varying greatly in form, position, and relations throughout the group. During mastication, the food is usually subjected to the action of saliva, a fluid furnished by special (salivary) glands. The saliva performs the twofold function of assisting in the deglutition of the food by rendering it moist, and of acting chemically upon the starch contained in the food, and thus rendering it more easy of digestion. The food being swallowed, passes down the "œsophagus" or "gullet" (*g*), to the stomach (*h*), where it is acted upon by the special secretion of that organ, termed the "gastric juice;" and by the action of this secretion is converted into a fluid mass, to which the name of "chyme" has been given. The "chyme" next passes into the first and longest portion of the intestinal

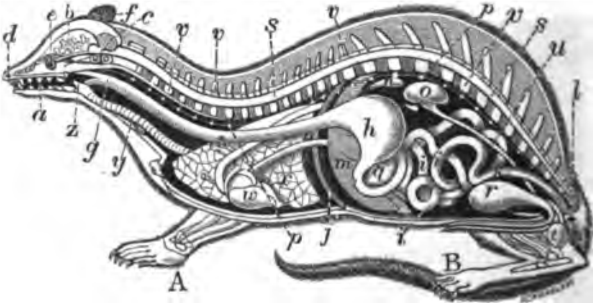


Fig. 92. IDEAL SECTION OF MAMMALIAN (VERTEBRATE) ANIMAL. (After Owen.)

A, "pectoral" or fore-limb; B, "pelvic" or hind-limb; *a*, cavity of mouth; *b*, cerebrum or brain proper; *c*, cerebellum or lesser brain; *d*, nose; *e*, eye; *f*, ear; *g*, œsophagus or gullet; *h*, stomach; *i i*, intestine; *j*, diaphragm or "midriff;" *k*, rectum or terminal portion of intestine; *l*, anus; *m*, liver; *n*, spleen; *o*, kidney; *p p*, sympathetic or ganglionic system of nerves; *q*, pancreas; *r*, urinary bladder; *s s*, spinal cord: *u*, ureter; *v v v v*, vertebral column; *w*, heart; *x*, lung; *y*, trachea or windpipe; *z*, epiglottis.

tract, termed the "small intestine" (*i i*); where the "bile" secreted by the liver (*m*), the "pancreatic juice" secreted by the "pancreas" or "sweet-bread" (*q*), and the "intestinal juice" furnished by the mucous glands of the intestine, severally act upon it; the result of the action of these secretions being the conversion of the "chyme" into a white fluid resembling milk, and termed "chyle." The indigestible and innutritious portions of the food are gradually passed onwards, and enter the "large" intestine (*k*), which forms the shorter portion of the intestinal canal, and which terminates usually by a distinct anal aperture (*l*).

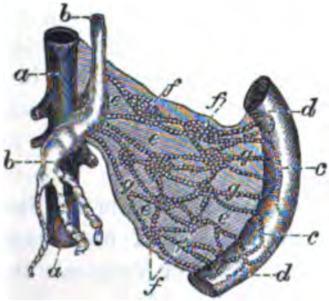
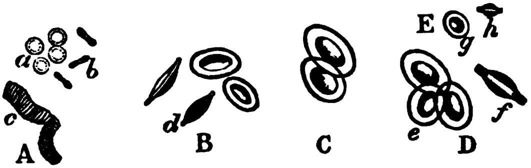


Fig. 93. **Absorbent System of Mammal.**

a a, Descending aorta or principal artery of the body: *b b*, thoracic duct; *c c*, origin of lymphatic or lacteal vessels (*g g*), from walls of intestine (*d d*); *e e e*, mesentery or membrane, attaching intestine to walls of body; *f f*, lacteal glands.

So far the process of digestion has proceeded; the next step introduces us to the "absorptive" system, which constitutes a characteristic feature of the Vertebrate type of structure. Throughout the Invertebrate series the products of digestion passed, in the less highly organised forms, simply from the digestive tract into the perivisceral sinuses, or into the general cavity of the body; or in more perfect forms the elaborated fluid was sent directly into the current of the circulation. But in the Vertebrata the process of absorbing the "chyle" or digestive product is performed by a special set of vessels forming the connecting media between the digestive and vascular systems, and to which the name of "lacteal vessels" has been given. These vessels (Fig. 93, *c c*, *g g*) ramify in the walls of the intestine (*d d*), and absorb the "chyle" as it passes along the intestinal tract, conveying it, after further elaboration in the "lacteal system," to the current of the circulation, which it enters by one of the large veins in the neighbourhood of the neck.

The conversion of nutrient matter into blood being understood, the blood itself may next in order be examined. The blood of Vertebrata is uniformly of a red colour, and when microscopically examined, the colour is seen to be due to the presence in the blood of an immense number of small bodies, generally of spherical shape, and to which the name of "blood-corpuscles" has been given. These corpuscles (Fig. 94) are suspended in a clear fluid—the "plasma"—and further exhibit, throughout the Vertebrate series, characteristic variations in size, form, and structure. Thus, the red blood-corpuscles of Fishes (Fig. 94, D E), Amphibians (C), Reptiles, and Birds (B), although differing in size and form, present a similarity in structure, in that each blood-corpuscle contains in its interior another and smaller corpuscle termed the "nucleus." Hence, the "blood-corpuscles" in these four classes are said to be "nucleated." In the Mammalia, on the other hand, the blood-corpuscles (Fig. 94, A, *a b c*) are devoid of a nucleus, and are accordingly said to be "non-nucleated." This cardinal fact regarding the "blood-corpuscles" of the various Vertebrate groups it is necessary to bear in mind, since various important generalisations in the classification of the group have been founded upon these differences in structure. The variations in form, and the differences in size, may also be noticed in the present instance. In the *Amphibia*, represented by Frogs and their allies, the largest corpuscles (Fig. 94, C) are found; the blood-corpuscles of Fishes and of Birds are also of considerable size as compared with those of Mammals, the smallest blood-corpuscle known, being that of the Musk Deer (*Moschus moschiferus*). In form also, the blood-corpuscles of Mammals differ from those of the other



94. Blood-Corpuscles of Vertebrata. (After Wagner.)

A, Red blood-corpuscles of Man; *a*, viewed flat surface towards the eye; *b*, in profile; and *c*, in rouleaux. B, Corpuscles in common Fowl; *d*, viewed sideways. C, Corpuscle of Frog (*Rana*). D, Corpuscles of Shark, (*Squalus*); *e*, viewed flat surface towards the eye; *f*, sideways. E, Corpuscles of Fishing-Frog (*Lophius*); *g*, flat surface; *h*, edgeways.

Vertebrate groups, the Mammalian corpuscles being, with few exceptions, circular, whilst those of the other groups, with one or two exceptions, are of oval or elliptical shape.

III. *The Hæmal, or Blood-Vascular System.*—With the exception of the Lancelet, all Vertebrates possess a contractile chamber or "heart" (Fig. 92, *w*), the office of which is to circulate the blood throughout the body. This organ varies considerably in the degree of perfection to which its morphological, as well as its functional relations attain; and in the present instance it may suffice to indicate the phenomena of the circulation in the higher members of the group; the various modifications being afterwards observed when treating of the special morphology of the Vertebrate classes. The most perfect and typical circulation is seen in Birds and Mammals, in which classes the circulation is said to be "double"—a term implying a subdivision of the circulatory process into two distinct yet connected parts. Thus the "greater" or "systemic" circulation (Fig. 95, *g*) is that through the body, whilst the "lesser" or "pulmonary" circulation (*k*) is that through the lungs, for the purpose of purification. Accordingly, the heart exhibits a double structure, being divided into a right and left side, and each side being further divided into two chambers or cavities—the smaller chamber of each side being known as the "auricle" (Fig. 95, *a c*), whilst the larger is termed the "ventricle" (*b d*). Functionally viewed, the right side of the heart is solely concerned with the "lesser" or pulmonary circulation (*k*), whilst the left side is exclusively devoted to carrying on the circulation through the system (*g*). With these two distinct sides of the heart, two distinct kinds of blood-vessels are in connection. The first of these take their origin from the left or systemic side of the heart,

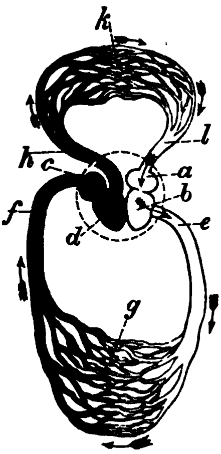


Fig. 95. DIAGRAM OF THE CIRCULATION IN MAMMALS.

(The course of the circulation is depicted as observed from behind—the observer's right thus corresponding with the *left* side of the heart.) The venous course of the circulation is indicated by the cross-shading, the arterial system being left white. *a*, Left auricle of heart; *b*, left ventricle; *c*, right auricle; *d*, right ventricle; *e*, aorta, or great artery, proceeding from left ventricle; *f*, *vena cava*, or great venous trunk, terminating in right auricle; *g*, systemic circulation; *h*, pulmonary artery, carrying venous blood to lungs; *k*, circulation in the lungs, or pulmonary circulation; *l*, pulmonary vein, returning purified or arterial blood to left auricle. The dotted circle represents the pericardium, or enveloping sac of the heart, and the arrows denote the course of the circulation.

and are known as "arteries" (*e*); the second set of vessels, known as "veins" (*f*), terminate in the right side of the heart. An intermediate set of vessels, termed "capillaries," serves to unite and connect the arteries and the veins, in a manner that will be apparent when the course of the circulation is understood.

In the Mammal and Bird, therefore, the pure or "arterial" blood from the lungs, rich in oxygen, and intended for the nourishment and repair of the tissues, enters the left auricle (Fig. 95, *a*), and this cavity contracting, the blood is sent into the larger chamber—the left ventricle (*b*),—regurgitation into the auricle being prevented by a valvular structure known as the "mitral" valve. From the left ventricle the blood is next sent into the "aorta," or great arterial trunk of the body (*e*), which, with its numerous branches, forming the arterial system, conveys the blood to all parts of the body. The arteries, ramifying throughout the system, gradually merge into the "capillaries," which in turn grow more and more minute, until they become of microscopic size, and so fitted to supply the intimate tissue structure with nutrient material. The nutrient function of the blood having been thus performed, and carbonic acid, heat, and water, having been returned to the blood as products of the tissue waste, the second part of the circulatory process may now be said to commence. This second process consists in the conveyance of the impure blood to the respiratory organs, a part of the function with which the right side of the heart has solely to do. The impure blood, therefore, passes from the capillaries into the veins—the relations of the arteries, capillaries, and veins being now apparent. The arteries thus carry blood from the heart to the system; the veins return blood to the heart from the system; whilst the capillaries form a connecting series of vessels, in which the blood from the arteries is brought directly into contact with the tissues, and by which, at the same time, the impure blood is gradually transferred to the veins.

Thus conveyed by the veins, the blood is returned to the heart in a venous condition. It has now assumed a dark or purple colour, consequent on the absorption of carbonic acid; pure, or arterial blood, on the contrary, being of a brighter or scarlet hue. The venous system terminates into two large venous trunks, known as "venæ cavæ" (*f*), which debouch into the right auricle of the heart (*c*); and by the contraction of this latter cavity, the blood is forced into the right ventricle (*d*)—regurgitation, as before, being prevented by a valve to which the name of "tricuspid" is applied. From the right ventricle, the venous blood is conveyed by the pulmonary arteries (*h*) to the lungs to be purified—the consideration of this process being included under the phenomena of respiration—and after purification, the now pure and arterial blood is returned by the pulmonary veins (*l*) to the left auricle, to be recirculated through the body as before.

Fresh nutrient matter, in the form of chyle, taken up from the digestive system by the lacteals, is at intervals, as previously noticed, poured into the current of venous blood which is being sent to the lungs; there, having been oxygenated, this new material, incorporated with the already circulating blood, is sent through the system, in turn to perform its part in the great function of nutrition.

IV. *The Respiratory System.*—Whilst in the lower Vertebrates, respiration, or the process of purification of the blood, is carried on by means of gills, or by gills in combination with lungs, the higher members of the group respire exclusively by lungs (Fig. 92, *x*). Functionally, the process is similar throughout the series, and consists essentially in the interchange of carbonic acid and oxygen gases—the former being excreted, the latter inspired; and the oxygenation of the blood being thus synonymous with the conversion of venous into arterial blood. In the lungs, on the intimate structure of which it will be unnecessary here to dwell, the venous blood is therefore exposed to the action of the oxygen contained in the inspired air; and is thus aerated and purified, the carbonic acid, heat, and water being at the same time excreted. As intimately associated with the lungs in the excretory process, the skin and kidneys may briefly be mentioned. The skin greatly aids the lungs in the work of excretion; a certain proportion of the water, and in most cases a determinable proportion of the carbonic acid also, being thus got rid of. On the kidneys devolves the no less important task of eliminating the nitrogenous waste of the body, represented in chief by the substance termed urea, together with water, and a small percentage of carbonic acid also. The excretion of the kidneys (Fig. 92, *o*), known as urine, is usually conveyed by two tubes, the "ureters" (*u*), to a distinct organ, the "urinary bladder" (*r*), whence it is excreted externally. In the lower groups of the Vertebrata the ureters open, with the "rectum," into a common chamber or "cloaca."

V. *The Nervous System.*—As previously noticed, the nervous system in the Vertebrata more particularly partakes of the high degree of specialisation peculiar to the group. Two distinct, yet connected systems of nerves exist in most Vertebrate animals; the one enclosed in the skull and vertebral column, and known as the "cerebro-spinal" axis (Fig. 92); the second, termed the "sympathetic" or "ganglionic system" (Fig. 92) of nerves; the centres of this latter system being disposed on the under surface of the vertebral column, and being thus contained within the visceral cavity of the body. The "cerebro-spinal" axis is that which is peculiar to the Vertebrate Series; it admits of division into the brain or "encephalon" (Fig. 92, *b*), and the spinal cord or "myelon" (*s s*). The "encephalon" is further divided into the "cerebrum" (Fig 92, *b*), or "brain proper" and the "cerebellum" or "lesser brain" (*c*); and from the brain itself, as well as from the spinal cord, nerves arise in symmetrical order, and are distributed to the organs and tissues of the body. In the "sympathetic" system (Fig. 92, *p p*), the symmetrical arrangement of parts is no longer seen, this system of nerves being represented by a series of large "ganglia," disposed in an irregular manner over the viscera generally; the term "ganglionic" being applied to the "sympathetic" system from this latter feature in its disposition. The physiology of these two centres of correlation in Vertebrate animals is also distinct, each system performing its own special duty in the great function of innervation. Thus, the "cerebro-spinal" axis is essentially connected with sensation and locomotion, and in the higher animals with volition and intelligence; and these functions being eminently characteristic of the animal world as distinguished from the plant creation, the "cerebro-spinal axis" has accordingly been said to preside over the functions of "animal" life. The "sympathetic" system of nerves is to a certain extent independent of the will, the function of these centres being to regulate the great vital processes of digestion, respiration, and circulation; and these functions being also performed by plants, the "sympathetic" system is accordingly said to govern the functions of "vegetative" life. Homologically regarded, therefore, the "sympathetic" system corresponds to the ordinary nervous system of the Invertebrate Series, the functions of life in the lower animals being essentially "vegetative" in their nature.

Reproduction in Vertebrate animals is effected in various ways, or rather by modifications of the same typical process. The sexes exist in different individuals throughout the group. The great majority of Vertebrates are either "oviparous,"—that is producing impregnated ova or eggs, from which the young are afterwards hatched, or "ovo-viviparous;" the eggs in this latter case being retained within the parent's body for a longer period, or until the young animal is hatched. In the higher Vertebrates the ova are hatched, and the young animal or embryo is retained within the body of the parent for a longer or shorter period; the young are, in this latter case, born alive, and in an advanced state of development; the term "viviparous" being applied to those animals in which the reproductive process thus assumes its most perfect phase.

CLASSIFICATION.—The simplest and most natural mode of classifying the Vertebrata, is that by which the sub-kingdom is divided into two great sections, distinguished by the presence or absence of gills. Thus the section of the *Branchiata*, or "Gilled" Vertebrata, includes the two classes of the Fishes (*Pisces*) and Amphibians (*Amphibia*); the presence of branchiæ or gills during the whole or a part of the animal's life, classifying these two groups in the Branchiate section. The Reptiles (*Reptilia*), Birds (*Aves*), and Mammals (*Mammalia*), accordingly, form the *Abranchiate* section, distinguished by the fact, that at no period of life do gills exist in any member of these several classes. Other and minor characteristics—such as the relative development of certain embryonic appendages, and the comparative temperature of the blood—have been also used to subdivide the group, or to supplement the above primary distinctive feature.

By Huxley the Vertebrata are divided into three great provinces or sections—(*a*) the *Ichthyopsida*, including the Fishes and Amphibians—this section corresponding to the *Branchiate* division above noticed; (*b*) the *Sauropsida*, including the Reptiles and Birds; and (*c*) the *Mammalia*, including the Mammals—the characteristic features of this latter group being regarded of sufficient importance to constitute the class itself as a primary division of the sub-kingdom. This classification, besides being the most recent, has the merit of not only bringing into notice many important and distinctive characteristics in the economy of the several Vertebrate classes, but also of uniting these classes into distinct provinces, separated from each other by as distinct and peculiar morphological features.

The Vertebrata are therefore classified according to the following table:—

VERTEBRATA.

PROVINCE A. ICHTHYOPSIDA.	Class 1. *Pisces.* Class 2. *Amphibia.*
PROVINCE B. SAUROPSIDA.	Class 3. *Reptilia.* Class 4. *Aves.*
PROVINCE C. MAMMALIA.	Class 5. *Mammalia.*

CHAPTER XX.

VERTEBRATA.

PROVINCE A—ICHTHYOPSIDA.

General Character and Structure of Pisces.

THE *Ichthyopsida*, or "fish-like" Vertebrata, forming the first Province of the present sub-kingdom, are represented by the two classes *Pisces* and *Amphibia*—the characters common to and uniting these divisions in one province, being found chiefly in the nature of the respiratory or breathing apparatus, which consists of gills—these organs persisting either throughout the whole or only a part of life; in the presence of nucleated blood-corpuscles; and in the absence of certain embryonic structures ("amnion" and "allantois"), to be noticed more particularly in the *Sauropsida*, in which forms these structures occur for the first time in the Vertebrate Series. The special and diagnostic characters of each class will be more appropriately considered when treating of the special divisions themselves.

CLASS I.—PISCES.

As scientifically defined, the class *Pisces*, or Fishes, includes those forms in which the respiratory process is carried on during the entire life of the creature by means of branchiæ or gills, the respiration being thus aquatic in its nature. The heart is usually and typically two-chambered, consisting of one auricle and one ventricle; and the limbs are mostly present in the form of fins. The form of the fish is admirably adapted for swift progression through the watery medium in which it lives, the shape of the body being so modelled, and the scales with which it is covered being so disposed, as to present the least possible resistance to the surrounding and opposing fluid.

The head is in general distinctly marked, and is joined directly to the trunk—no true neck being observable. The body tapers gradually towards each extremity, and in general is flattened vertically, or from side to side. In some cases, however, and typically in the Skates and Rays, the body is compressed from above downwards, and presents broad dorsal and ventral surfaces; whilst in the so-called Flat-fishes (*Pleuronectidæ*), represented by the Soles, Plaice, and their allies, the body, although apparently flattened on the dorsal and ventral surfaces, is not so in reality—the body being in these latter cases greatly compressed from side to side. The bones of the head, in this instance, are further curiously modified, both eyes being thus brought to one side of the body, which is bordered by long "dorsal" and "anal" fins. These fishes therefore rest on one side, and not, as generally supposed, on the lower or ventral surface of the body.

The integument in Fishes presents some very interesting features for consideration. In all, the skin is more or less tensely stretched over the subjacent tissues, and appears to be lubricated by a mucous or oily secretion, furnished by a special glandular system, to which reference will be more fully and subsequently made. In general, the body is covered with imbricated plates or "scales," which are to be regarded as peculiar developments of the "epidermic exoskeleton," and which, overlapping each other, after the manner of house-tiles, thus constitute a most perfect armour-casing and protection for the body. The scales vary greatly in form, size, and texture, and present so many and striking differences, that Professor Agassiz has proposed to classify the group in accordance with the variations presented by these appendages. The most common form of scale is that seen in nearly all our common Fishes, and to which, from its more or less rounded shape, the term "cycloid" has been applied. The "cycloid" scale, depicted at A, Figure 96, essentially consists of a thin horny plate of circular shape,

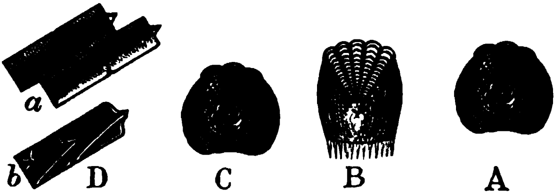


Fig. 96. Scales of Fishes (after Owen).

A, "Cycloid" scale (*Salmon*). B, "Ctenoid" scale (*Perch*). C, "Placoid" scale (*Ray*). D, "Ganoid" scales (*Amblypterus striatus*) (Carboniferous); *a*, upper surface; *b*, under surface, showing articulating processes.

lowed out in front and behind, the apposition of two vertebræ producing a distinct cavity (Fig. 97, B, *c*), which, during the life of the animal, is filled with a gelatinous substance, the remains of the "notochord" of early and embryonic life; this arrangement permitting of that amount of free movement and flexibility of the spine, so necessary to the due performance of the rapid movements observed in the locomotion of the fish. In one single example only—the Bony-Pike (Fig. 103)—is a different arrangement of the vertebræ met with. In this form, the anterior or front surfaces of the vertebræ are convex, whilst the posterior or hinder

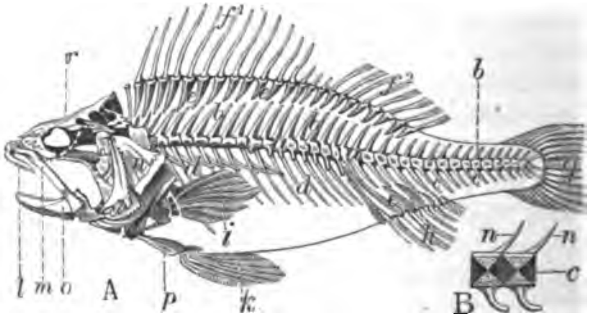


Fig. 97. OSTEOLOGY OF FISHES.

A, Skeleton of Perch (*Perca*): *a a*, vertebral column; *b b b*, superior or neural spines; *c c*, inferior or hæmal spines; *d d*, ribs; *e e e*, inter-spinous bones; f^1, fin-rays of first dorsal fin: f^2, fin-rays of second dorsal fin; *g*, caudal fin; *h*, anal fin; *i*, left pectoral fin; *k*, fin rays of left ventral fin: *l*, inter-maxillary bone; *m*, upper maxillary or jaw-bone; *n*, operculum; *o*, lower maxillary or jaw-bone; *p*, pelvic arch; *r*, frontal bone.

B, Section of vertebral column of fish (*Scarus*), showing the neural spines (*n n*), and the cavities (*c*), formed by the apposition of the "amphicœlous" vertebræ.

surfaces are concave; a ball-and-socket joint being thus formed by the approximation of the vertebræ to each other, and the term "opisthocœlous" being applied to the modification of structure thus observed.

The abdominal and caudal vertebræ bear distinct neural spines (superior spinous processes) (Fig. 97, *b b*), the caudal vertebræ in like manner bearing long hæmal or inferior spines (*c c*); the ribs (*d d*), which are confined to the anterior abdominal segments, springing from the "transverse processes" of these vertebræ. These ribs articulate each with but a single vertebra, and are not attached in front to any distinct "sternum" or breastbone, their free extremities being imbedded in the muscular walls of the abdomen; the ribs in turn usually bear small processes (Fig. 97 *d d*), which serve to fix them more securely in the adjacent tissues. The "sternum," as such, is wanting; although occasionally it would appear to be represented by rudimentary ossifications in the abdominal wall. No true thoracic or chest-cavity is therefore to be distinguished in Fishes, the ribs bearing no relation to the respiratory function, and merely sufficing to support the muscular walls of the body. The "interspinous bones" of Fishes (Fig. 97, *e e e*), are a series of bones supported on the spinous processes of the vertebræ, and serving in turn to attach and support the rays of the "median" fins (f^1, f^2, *h*), to which attention will be presently directed.

The skull of Fishes presents an exceedingly intricate and complicated structure, and in the present instance it may suffice to merely mention those points in its conformation which it is most essential to understand. The chief of these are the structures connected with the respiratory function, and which involve the consideration of the morphology of the "gill-cover" or "operculum" (Fig. 97, *n*). This structure consists of a series of bones, known as the "opercular bones," connected to each other by membrane, and forming, as its name implies, the lateral wall of the "gill," or "branchial" chamber of the fish. The "hyoid" or "tongue" bone of fishes also exhibits a peculiarity in development, in that it not only gives support and origin to the tongue, but gives attachment to the structures of the respiratory apparatus also.

The "fins" of Fishes, as representing the limbs, evince the greatest departure from the ordinary type of locomotive appendages among the Vertebrata. These organs are divisible into two distinct series, respectively denominated the "paired" and the "unpaired" or "median" fins. The homology of these two series of fins is also different; the former, or "paired fins," being homologous with the limbs of other Vertebrata, whilst the latter series are to be regarded as mere appendages of the epidermis, and as parts of the exoskeleton. The paired fins are known as the "pectoral" (Figs. 97, *i*, and 98, *p*) and "ventral" fins (*k*, *v*), and are typically four in number, although sometimes the "pectoral," and in many cases the "ventral" pair are absent; these latter fins especially presenting many variations in size, form, and situation. The "pectoral" fins (Figs. 97, *i*, 98, *p*), corresponding to the "anterior" or "pectoral" limbs of other Vertebrates, are situated anteriorly, and on the breast of the fish. The homology of the endoskeleton of the limbs (Fig. 97) can in most instances be satisfactorily determined—the homologues of the "scapula" or shoulder-blade, of the "coracoid bone," and of the "clavicle," being usually traceable. Of the bones of the arm proper, the "humerus" may be rudimentary; the "radius" and "ulna" are generally distinct; the "carpus," or "wrist," is represented by several small bones, varying in number; and lastly, the "fin-rays" (Fig. 97, *i*) represent the "metacarpus" and "phalanges" of higher forms. The endoskeleton of the "ventral" fins (Fig. 97, *p*, *k*) also partakes of the modification in structure, to which, as previously remarked, these latter members are subject. The ventral fins may occupy two distinct positions in Fishes. They may either be situated close to the anal fin (Fig. 102), when they are said to be "abdominal" in position; or they may be placed close to and underneath the "pectorals" (Fig. 98, *v*), in which case they are termed "thoracic" or "jugular" in position. The "pelvis" (Fig. 97, *p*) is generally represented by two cartilaginous pieces, imbedded in the muscular tissues of the abdomen, and entirely unconnected with the vertebral column when the "ventral" fins are "abdominally" situated. The "femur" or "thigh-bone," and the "tibia" and "fibula," as representing the leg, are entirely wanting in the posterior members; the "metatarsus" and "phalanges" or "toes" being represented by the "fin-rays" (Fig. 97, *k*), which, in this case, are directly attached to the representatives of the pelvic arch (p). When the ventral fins are "thoracic" in position, their endoskeleton is attached more or less intimately to that of the "pectoral" fins.

The "median," "unpaired," or "azygos" fins, vary greatly in number and disposition, but three distinct sets are generally to be perceived. Of these, the "dorsal" fins (Fig. 98, d^1, d^2) are those which are situated in the middle line of the "back;" the "anal" fins (Fig. 98, a) are placed on the ventral surface of the body, and, as their name implies, near the anal aperture; whilst the third and last example of the "median" fins is found in the "caudal" or "tail fin" (Fig. 98, c), which forms the chief agent in the locomotion of the fish. The structure of the "median" fins is essentially the same throughout, these organs being supported upon "fin-rays" (Fig. 97, f^1, f^2, h), united by movable articulations with the "interspinous bones" (Fig. 97, e e), upon which they are supported. The

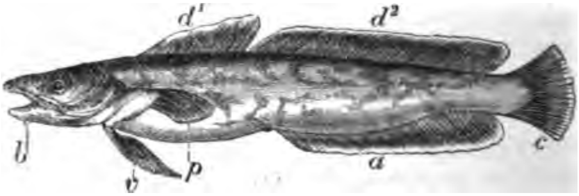


Fig. 98. MORPHOLOGY OF FINS.

Ling (*Lota molva*); *a*, "anal" fin; *b*, "barbule;" *c*, "caudal" fin; *d*¹, first "dorsal" fin; *d*², second "dorsal" fin; *p*, left "pectoral" fin; *v*, left "ventral" fin.

morphology of the "caudal" fin forms the only remaining point to which attention need in the present instance be directed. The "tail-fin" in Fishes is formed upon one or other of two distinct types. In the first of these, to which the term "homocercal" tail is applied, and which is exemplified by the great majority of living Fishes, the lobes of the tail are equally developed (Figs. 97, *g*, and 98, *c*)—the vertebral column forming no part of the fin, and the "tail-fin" being symmetrically disposed on each aspect of the spine. In the second, or "heterocercal" variety, the lobes of the "caudal" fin are unequally developed (Figs. 102, A, B, and 103, A, B), the spine running into the upper and developed lobe of the tail. This latter type is represented by a few existing forms, such as the Sturgeon, Sharks, Dog-fishes, etc., and also by the great majority of extinct and fossil species (Fig. 104, *c*).

The digestive system of Fishes presents certain points worthy of consideration. The teeth are usually present in great number; and concerning these organs, the peculiarities of the dental arrangement in Fishes may be summed up under three heads. Firstly, their number, the teeth being present in great plenty; and these organs not being confined to the jaw-bones, as in higher forms, but being borne by nearly every bone which enters into the formation of the mouth. Secondly, that the teeth are not lodged in sockets, but are attached by ligaments to the surface of the bones upon which they are set; or they may be simply imbedded in the mucous membrane of the mouth.

Further, in some cases the ligaments attaching the teeth to the bones are highly elastic, permitting of the depression of the teeth on the entrance of food, and of their subsequent and instantaneous return to the normal position. The advantage of the recurved form of the teeth also, in permitting the entrance of objects of considerable bulk to the mouth, but preventing the withdrawal of such objects, will also be readily perceived. Thirdly, that the teeth of Fishes undergo renewal or repair after displacement or injury, or when worn away by simple attrition, a fresh posterior set being developed; or, in the case of many Fishes—exemplified by the Sharks—two or three sets may be found, prepared to take the place of those which are lost or worn away.

The œsophagus (Fig. 99, *c*) is generally short, dilatable, and muscular, and opens into a distinct stomach (*d*), the "pyloric" or posterior aperture of which is generally provided with a muscular valve. Attached to the posterior extremity of the stomach, a number of "cæcal" or "blind" appendages (*g*), known as the "pyloric cæca," are usually found. These organs vary in number from one to sixty, and are supposed to represent the pancreas—this organ, however, being found in certain Fishes in which the "pyloric cæca" are also present. The intestine (*e e e*), after a few convolutions, terminates in the posterior anus (*f*). The division into the large and small intestine is generally, but faintly, indicated—the large intestine, in the majority of instances, being represented by a mere increase of width in the intestine, just before it terminates in the anus. In some Fishes, and more particularly in the Sharks and Rays, the mucous or lining membrane of the intestine is arranged in spiral or screw-like folds (Fig. 99, B), which serve materially to increase the absorptive and digestive area of the structure.

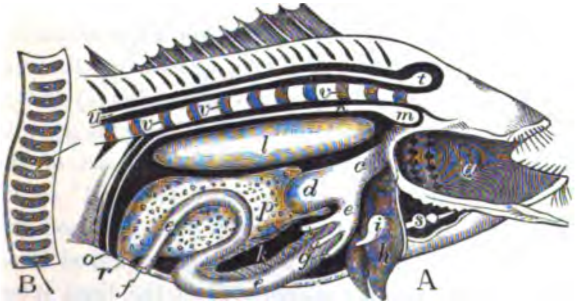


Fig. 99. Anatomy of Fish.

A, Diagrammatic section of Fish (after Jones); *a*, cavity of mouth, showing branchial apertures; *c*, œsophagus; *d*, stomach; *e e e*, intestine; *f*, anus; *g*, pyloric "cæca" or appendages; *h*, liver; *i*, gall-bladder; *k*, spleen; *l*, air-bladder; *m*, kidney; *n*, ureter; *o*, external opening of ureter; *p*, ovary; *r*, termination of oviduct; *s*, heart; *t*, brain; *u*, spinal cord; *v v v*, vertebral column. B, Section of Shark's intestine, showing spiral arrangement of mucous membrane.

No distinct salivary glands are developed in Fishes, the place and function of these glands being subserved by a special development of the mucous glands of the mouth, and in all probability by the "pyloric cæca" (*g*) also. The liver (Fig. 99, *h*) is generally large, and furnished with a gall-bladder (*i*), the ducts of which open into the intestine, posteriorly to the pyloric aperture. The spleen (*k*) is of small size, whilst the kidneys (*m*) are invariably large, lying immediately beneath the spine, and their efferent ducts or "ureters" (*n*) opening either into a common chamber or "cloaca," or by a separate and distinct aperture (*o*).

The circulatory process in Fishes is carried on by means of a two-chambered heart (Fig. 99, *s*), consisting typically of an auricle (Fig. 100, *a*), receiving the venous blood from the body, and of a ventricle (*b*) driving it for purification to the "branchiæ" or gills (*e*). As seen in the accompanying diagram, the heart of the Fish is purely "respiratory" or "branchial" in its character, its sole function being to send the blood into the respiratory organs for aëration—the purified blood thus returning to the system without the direct intervention of the heart. The functional or physiological aspect of the circulatory process in the Fish, is thus essentially different from that observed in the ordinary Mollusc; the heart of the latter form being purely *systemic* in character, and being used exclusively to distribute the purified blood through the system. The branchial artery (Fig. 100, *d d*) in the Fish, as it leaves the ventricle (*b*), usually dilates into a bulb or chamber termed the "bulbus arteriosus," or "arterial bulb" (*c*). This chamber, in certain instances, is provided with highly muscular coats, and is also sometimes furnished with a complicated valvular apparatus—the "bulbus arteriosus" in these cases forming a third contractile chamber, and serving to aid the ventricle in driving the venous blood to the gills for purification.

In Fishes the "portal system" of veins, characteristic of the Vertebrate series, is first observed. In virtue of this arrangement the veins from the stomach, intestines, and other viscera, pour their blood into the liver, instead of conveying their contents to the heart—the bile being elaborated from the supply of venous blood thus provided. In all Fishes, with one exception—the *Amphioxus* or Lancelet—the blood is red; the blood-corpuscles of Fishes being nucleated (Fig. 94, D, E), in common with those of the *Sauropsida*.

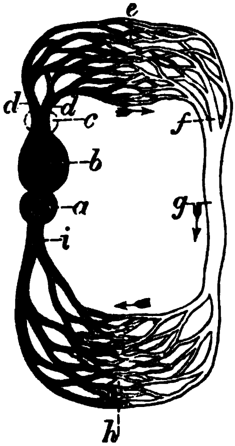


Fig. 100. THEORY OF CIRCULATION IN FISHES.

a, Auricle of heart; *b*, ventricle; *c*, *bulbus arteriosus*; *d d*, branchial arteries, conveying venous blood to gills, and branchial circulation (*e*); *f*, branchial veins, pouring purified blood into aorta (*g*); *h*, systemic circulation; *i*, vena cava, receiving venous blood from the system. The venous blood is indicated by the shaded portion; the arterial by the white. The arrows indicate the direction of the circulation.

In the present instance, the aquatic form of the respiratory process, as also the structure of the corresponding respiratory organs or gills, are seen in highest perfection. The "branchiæ" consist of membranous and vascular tufts or laminæ, developed on cartilaginous arches, known accordingly as "branchial arches;" these latter corresponding to the "posterior visceral clefts," which, as previously mentioned, remain in the Fishes and Amphibians persistent through life. The "branchial arches" are intimately connected with the "hyoid bone," and are contained in special chambers ("branchial" or "gill chambers"), one of which is situated on each side of the pharynx or posterior portion of the mouth. The "branchial chambers" communicate with the cavity of the mouth by a series of slits or fissures in the inner or pharyngeal walls of the chambers, to which the term "branchial fissures" (Fig. 99, *a*) is applied. Water is admitted, as in swallowing, to the pharynx, passes through the branchial fissures into the "gill-chambers," and thus provides for the due oxygenation of the blood; whilst the effete water is expelled through the posterior "gill-slits" or "opercular" openings, situated at the hinder margin of the "opercula" or "gill-covers," by the combined muscular action of the "gill-covers" and "branchial arches."

In most Fishes an organ, presenting features of somewhat anomalous and peculiar character, both in its morphological and physiological aspect, and termed the "air" or "swimming bladder" (Fig. 99, *l*), is found. The "air-bladder" consists of a membranous sac, furnished with muscular and contractile fibres, and placed usually beneath the vertebral column. In most instances the sac consists of but a single cavity, whilst in other cases it is divided into two or even three "loculi" or chambers. Usually the "air-bladder" presents the form of a simple shut sac (*l*); but in other instances it communicates with the pharynx or stomach by a distinct tube, or "pneumatic duct." The contained gas also varies in constitution—in some cases nitrogen gas, in others, oxygen being found. The former gas is principally found in the "air-bladders" of Fishes inhabiting fresh-water lakes and rivers, whilst those of the sea Fishes chiefly contain the latter gas. The obvious use of the "swimming-bladder" is to act as a hydrostatic apparatus, and, by altering the specific gravity of the Fish, enabling it to rise or sink in the water—the necessary condensation or expansion of the contained gas being accomplished by the contraction or relaxation of the muscular fibres with which the organ is provided.

Whilst, as previously remarked, the "swimming-bladder" is present in the majority of Fishes, certain Fishes, in which such an organ would apparently have been of the greatest service, do not possess this organ; and, on the other hand, it is present in several instances where, from the limited character of the movements of the Fishes, the "air-bladder" would appear to be comparatively useless. A careful study, however, of the homology of this peculiar organ serves to explain away much that would otherwise appear strange, or even inexplicable, since the "air-bladder" of the Fish is undoubtedly homologous with the lungs of other Vertebrates. This homology is clearly traceable from its subdivision in some instances into two parts; from its cellular structure in others; from the comparison of its efferent duct with the "trachea" or "windpipe" of higher forms; or, best of all, from finding in the *Lepidosiren*, or "Mud-fish" (Fig. 105), the air-bladder undergoing further development—becoming more cellular and lung-like in its structure—subserving in this animal the function of true lungs; and thus demonstrating its true and undoubted homology—and in this latter case its analogy also—with the lungs of higher forms.

In their nervous system, Fishes exhibit a type of organisation decidedly inferior, in many respects, to that of the other Vertebrate groups. The cranial cavity is of small size; and, save in the Sharks and their allies, the chief nervous centres are but imperfectly developed. The senses, however, are generally well developed throughout the class. The sense of sight, in particular, is possessed in great perfection, the optic nerves being of considerable size. The auditory or hearing sense is present in the great majority of forms, and is subserved by an auditory vesicle containing "otoliths," together with other and rudimentary structures, homologous with essential parts in the more perfect ear of higher forms. The auditory organ, however, is completely enclosed within the head, and in no Fish does any external auditory opening exist. Organs of smell exist in all Fishes, but the nasal cavities,—save in two instances—the *Myxine* or Hag-fish, and the *Lepidosiren* (Fig. 105),—are shut sacs, no communication existing between the nostrils and the cavity of the mouth. The sense of touch appears to be subserved in certain cases by special filaments or "barbules" (Fig. 98, *b*), situated in the neighbourhood of the mouth, or which in some cases are found attached to the pectoral fins. The so-called "lateral lines," observed running along the sides of most Fishes, are also supposed to subserve some part of the sensory function. Each "line" is formed by a series of special scales, perforated each by a minute tube, which leads into a common canal, following the course of the "lateral line;" this canal also communicates with certain cavities situated in the head, and to which a special nervous supply is distributed. The "lateral lines," and their accompanying apparatus, were formerly supposed to be connected with the secretion of the mucus with which the bodies of Fishes are lubricated, but the relations of the system would appear to render the former view of their function the more probable and correct.

Lastly, in several Fishes special organs are met with, by means of which they are enabled to communicate electric shocks to any animal with which they come in contact. Of these the most familiar are the *Torpedo* or Electric Ray, and the *Gymnotus* or Electric Eel of South American rivers. The electrical organs consist of special masses of cellular structure, richly supplied with nervous filaments; the *rationale* of the action by which these peculiar organs are brought into play, being the conversion of nervous energy into electricity, just as muscles convert the same energy into ordinary motion.

In their reproduction, Fishes generally exemplify the "oviparous" mode of that process, that is, they produce fertilised eggs, from which the young are afterwards hatched. The "ovaries" or "roe" (Fig. 99, *p*), when distended with ova, occupy the greater part of the abdominal cavity; whilst the male organs, known as the "milt" or "soft roe," occupy a position similar to that of the ovaries in the female. The ova escape from the ovarium, either into the abdominal cavity, from which they find their way into the external medium by special openings termed "abdominal pores" (Fig. 101, A, *p*); or in other cases the efferent ducts of the ovaries, known as "oviducts," terminate by special apertures (Fig. 99, *r*), placed usually in close promixity to the anal orifice; or lastly, these tubes may open into a "cloaca" or chamber, common to the ducts of the alimentary, generative, and renal systems.

In the Sharks and their allies, however, the ova are retained within the body of the parent until the embryo is nearly developed; the reproduction in these forms being classed under the "ovo-viviparous" division of the process.

CHAPTER XXI.

CLASSIFICATION OF PISCES.

The classification of this extensive group has, as might be expected, been subject to great variation; the number of species, and the close resemblances existing between the various members of the group, rendering the arrangement of the class into concise subdivisions an extremely difficult and laborious task. According to Huxley, the Class Pisces is divisible into the following six orders:—

Order 1. *Pharyngobranchii.* Ex. Lancelet (*Amphioxus*).
Order 2. *Marsipobranchii.* Ex. Lamprey (*Petromyzon*).
Order 3. *Elasmobranchii.* Ex. Shark (*Carcharias*), etc.
Order 4. *Ganoidei.* Ex. Sturgeon (*Accipenser*).
Order 5. *Teleostei.* Ex. Salmon (*Salmo*), etc.
Order 6. *Dipnoi.* Ex. Mud-fish (*Lepidosiren*).

Order 1. *Pharyngobranchii* (*Cirrostomi*).—As implied by the technical name of this group, the respiratory organs exist as intimate parts of the pharynx—true branchiæ or gills being absent. The *Amphioxus* or

Lancelet (Fig. 101, A)—a form, the anomalous nature of which has been previously alluded to—is the sole representative of this order. The Lancelet is found inhabiting the sandy coasts of the world generally, and derives its familiar name from the lance-shaped form of the body.

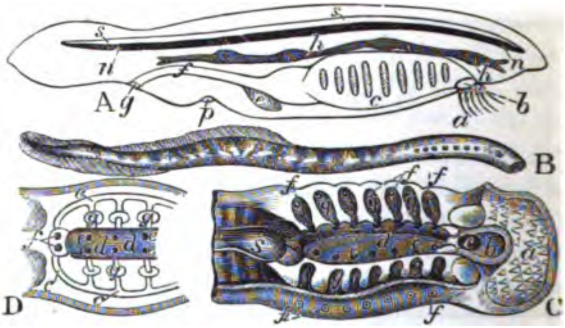


Fig. 101. PHARYNGOBRANCHII AND MARSIPOBRANCHII.

A, Diagram of Lancelet (*Amphioxus*) (altered from Huxley); *a*, cartilaginous "cirri" surrounding the mouth (*b*); *c*, pharynx, with branchial clefts; *e*, liver; *f*, intestine; *g*, anus; *h h*, circulatory system, with contractile dilatations; *n n*, notochord; *s s*, spinal cord; *p*, "abdominal pore." B, Lamprey (*Petromyzon*). C, Branchial apparatus of Lamprey; *a*, cavity of mouth, with teeth; *b*, pharynx; *c*, opening of tube from dorsal surface of the head; *d d*, continuation of pharynx to form a respiratory tube, common to the gill-sacs of both sides; *e e*, pharyngeal openings of gill-sacs (*g g g*); *f f f*, external openings of gill-sacs; *s*, stomach. (The upper gill-sacs are represented as having been opened.) D, Branchial apparatus of *Myxine*; *c c c*, common respiratory tubes, opening by two apertures at *f*; *d d*, pharynx; *e e e e*, pharyngeal openings of the gill-sacs; *g g g*, gill-sacs.

An expansion of the dorsal integument forms a rudimentary dorsal fin, whilst a caudal fin, of pointed shape, and an anal fin, are also present. The paired fins, representing the limbs, are undeveloped.

The endoskeleton is entirely represented by the persistent semi-gelatinous "notochord" (Fig. 101, *n n*), no defined skull, lower jaw, or ossifications of any kind being found in the present instance. The mouth (Fig. 101, *b*) is represented by an opening of longitudinal shape, situated anteriorly, and is provided with a number of cartilaginous filaments, termed "cirri" (*a*), from the presence of which the name "Cirrostomi," sometimes applied to this group, is derived. The oval opening leads into the greatly developed "pharynx" (*c*), and from the posterior extremity of the pharynx the alimentary or digestive tract is continued—no dilatation meriting the distinctive name of stomach being observed. The intestine (*f*) terminates in a distinct anal aperture, depicted at *g*. A rudimentary liver (*e*) is also to be noticed; and the existence of kidneys, although considered doubtful by some authorities, has, nevertheless, been pretty accurately determined.

The circulatory system—seen in the present instance in its most primitive condition among the Vertebrata—consists of a series of contractile dilatations, situated on several of the principal blood-vessels (Fig. 101, A, *h h*). The most typical of these dilatations, and that which approaches most nearly the character of a true circulatory organ, is situated on the great pharyngeal vessel which receives the venous blood from the body, and distributes it through the network of blood-vessels in which it is exposed to the aërating influence of the water admitted to the pharynx (*c*). This latter chamber consists of a dilated sac, which communicates with the exterior by the mouth, and with the cavity of the abdomen by means of a series of slits or clefts in its walls. The walls of the pharynx are further provided with cartilaginous filaments—the homologues of the "branchial arches" of higher forms—furnished with delicate vascular fringes; whilst anteriorly the pharynx is provided with free "vascular lamellæ," which, doubtless, in some degree subserve the respiratory process. The mucous or lining membrane of the pharyngeal sac is richly provided with vibratile cilia, the function of which, in promoting the free circulation of water throughout the organ, will be readily understood. Respiration is therefore accomplished in the Lancelet by the admission of water through the oral opening into the "pharyngeal" or "branchial" sac (*c*); the venous blood contained in the vessels of the pharynx being thus submitted to the influence of the oxygen. The effete water of respiration passes through the clefts in the pharyngeal walls, and enters the abdominal cavity, from which it is expelled by an opening known as the "abdominal pore" (*p*), which also serves as an aperture of exit for the products of the generative system.

The nervous system is of a very rudimentary type of structure, consisting simply of a spinal cord (*s s*), without any distinct expansion into a brain, and from the anterior extremity of which, nervous filaments are given off to the region of the mouth, and to the eyes, —which latter organs are also of the most rudimentary description. An olfactory organ is believed to be represented in a ciliated sac, situated on the dorsal aspect of the head.

Reproductive organs, in the form of ovaria and testes, also exist, the ova escaping, as previously mentioned, by the "abdominal pore" (*p*).

Order 2. *Marsipobranchii* (*Cyclostomi*).—The members of the present group, represented by the Lampreys, (*Petromyzonidæ*), (Fig. 101, B), and Hag-fishes (*Myxinidæ*), whilst exhibiting a structure decidedly superior to that of the preceding order, nevertheless present several important characters, indicative of their inferiority to the ordinary piscine organisation. The body is of elongated shape, the paired fins being absent in this case also; and the median fins being represented by an expansion of the integument, which fringes the dorsal and also the ventral margin of the body.

The "notochord" is still persistent, but a distinct skull, in which cartilaginous elements appear to enter, is also present. A lower jaw is undeveloped in this, as in the previous instance.

The mouth exists as a round sucking-disc (Fig. 101, B); the conformation of the oral opening in this order suggesting the term *Cyclostomi*, by which name the group is sometimes known. The mouth is usually provided with teeth (Fig. 101, C, *a*), these organs being borne on the palate, tongue, or upon special cartilages (labial cartilages), developed in the neighbourhood of the lips. The teeth vary in number, the dentition of the *Myxine* or Hag-fish forming one of the most peculiar features in its organisation. This latter form possesses a single recurved tooth of large size, situated in the centre of the palate; in the Lamprey, however, numerous teeth are developed, these organs being in this latter case borne by the palate, lips, and tongue.

The digestive system consists of a distinct stomach and intestine; the liver and kidneys being well developed.

Circulation is performed by a distinct heart, formed on the ordinary piscine type, and therefore consisting of an auricle and ventricle. The form and disposition of the respiratory apparatus, however, exhibits, as in the previous instance, a departure from the typical structure of those organs in the present class, this peculiarity giving rise to the technical designation of the order. The respiratory organs in the present instance, therefore, exist as sac or pouch-like cavities (Fig. 101, C and D, *g g g*), developed in the sides of the pharynx (*d*). These sacs communicate externally by distinct apertures (*f f f*), whilst internally, they open, either directly into the pharynx (D, *d*), or indirectly, by a common respiratory or branchial tube (C, *d*). The lining membrane of these sacs is highly vascular, and is thrown into numerous "rugæ" or folds, over the surface of which the capillary blood-vessels, carrying venous blood, are thickly distributed.

In the Lamprey, as depicted in Fig. 101, C, the gill-sacs (*g*) number seven on each side, and communicate externally by as many distinct apertures (*f f f*), opening on the sides of the neck. Water is admitted for the purpose of respiration by the external apertures (*f f*) of the respiratory sacs, and after circulating freely throughout the branchial apparatus, is expelled by the same orifices. At other times water is admitted to the respiratory organs, by means of a distinct tube (Fig. 101, C, *c*), leading from the pharynx, and opening externally on the dorsal aspect of the head.

In the Hag-fishes the disposition of the respiratory apparatus is essentially similar to that just described in the case of the Lampreys; the external openings of the gill-sacs in the former, however, numbering two only, and these being placed on the under surface of the head. As shown in the accompanying illustration (Fig. 101, D), the sacs in the *Myxine* open into two common respiratory tubes (*c c*), which terminate in the two external openings figured at *f*. The structure of the branchial apparatus in these forms is peculiarly adapted to suit their mode of life. These creatures attach themselves by their sucker-like mouths to fixed objects, and thus preclude the admittance of water to the branchial sacs by the mouth, as in other fishes, whilst, by means of the external openings of the respiratory organs, free communication between the external medium and the respiratory organs is nevertheless maintained.

The brain evinces a comparatively high organisation, and the senses are also present in tolerable perfection. The eyes are well developed, and an auditory organ, of simpler construction than that found in other fishes, is also to be noticed. The tactile sense is, in all probability, subserved by the cirrous filaments with which the mouth is fringed. The disposition and structure of the olfactory organs forms not the least remarkable feature in the organisation of the present group. The nostrils are represented by a sac, opening externally by a single aperture; and in the *Myxine*, as previously noticed, the nostril opens posteriorly into the cavity of the pharynx. In the Lampreys, and in all other fishes, with the second exception of the *Lepidosiren* or Mud-fish, the nostrils are closed sacs, which do not communicate with the cavity of the mouth.

The reproductive organs underlie the spinal column, their products escaping into the abdominal cavity, whence they are expelled into the outer world by an "abdominal pore."

The Lampreys are represented by the Sea Lamprey (*Petromyzon marinus*), and by the River Lamprey (*P. fluviatilis*), (Fig. 101, B). The former ascends rivers in the early spring, for the purpose of spawning. The Hag-fish (*Myxine glutinosa*) derives its specific appellation, from the large quantity of mucus, which, when captured, it gives off from its skin. It is commonly found inhabiting the bodies of other Fishes, into which it bores its way, by means of the palatine tooth or fang previously noticed.

Order 3. *Elasmobranchii.*—The members of this group, which is typically represented by the Sharks and Rays, are distinguished by the variable structure of the vertebral column, which ranges from a mere fibrous "notochord," to a completely ossified spinal column.

The skull is cartilaginous, and a distinct lower jaw is present. The integument is not covered by scales disposed in a regular manner, but is studded over by bony tubercles, or by placoid scales, the structure of which has been already described. True dermal spines are also developed in the present instance; these latter structures being principally found in the neighbourhood of the dorsal fins. The "paired" fins are invariably present. Of these the "pectoral" fins in the Skates and Rays attain a very large size, as compared with that of the body; this feature producing the flattened conformation of these fishes; whilst in all the members of this group, the "ventral" fins are "abdominal" in position. The "caudal" fin in this group is usually of the "heterocercal" variety; several species exhibiting this peculiar conformation of the tail in a very characteristic manner. (Fig. 102, A, B.)

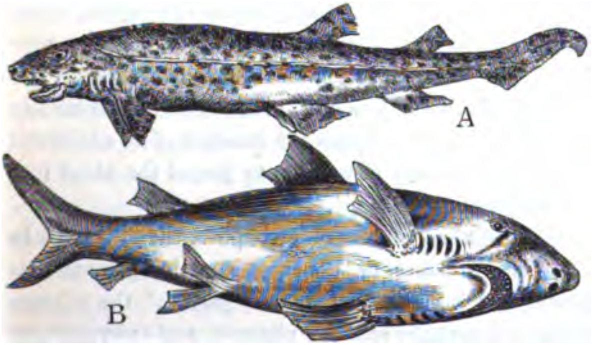


Fig. 102. Elasmobranchii. (After Yarrell.)
A, Small-spotted Dog-fish (*Scyllium (Squalus) canicula*). B, White Shark (*Carcharias vulgaris*), showing mouth and branchial clefts.

The teeth are usually very numerous, and present, in several members of the group, a highly characteristic appearance. The intestine is generally short, but the spiral arrangement of the mucous membrane (Fig. 99, B), previously alluded to, serves materially to increase the digestive area of the gut. The intestine terminates, with the efferent ducts of the urinary and generative organs, in a common chamber or "cloaca."

The structure of the heart in the Elasmobranchii presents several features worthy of notice. The "bulbus arteriosus" (Fig. 100, *c*) is specially developed; being furnished with striated muscular fibres, and also provided with several transverse rows of valves. The "arterial bulb," in this case, is therefore "rhythmically contractile," and performs the function of an additional chamber, in aiding materially to propel the blood into the respiratory organs.

As the name of the order implies, the gills exist in the form of sacs or pouches, containing numerous thickly-set vascular laminæ or "plates;" the gill-sacs opening internally into the pharynx, and externally, by a variable number of clefts or fissures situated on the sides of the neck (Fig. 102). Water is admitted by the mouth, and gains access to the gills through the pharyngeal clefts; the effete water of respiration being expelled by the external openings. In certain members of this group, typically represented by the Sharks, water can be admitted to the gills by means of two tubes, which open on the upper surface of the head by two apertures, termed "spiracles;" these tubes lead directly into the pharynx, whence the water gains access to the gill-sacs.

A distinct swimming bladder is absent in the *Elasmobranchii*, but traces of a rudimentary and homologous appendage have been observed in certain members of the group.

The nervous system attains, in this order, its highest development in the class of Fishes—the relative size and development of the brain especially, as also the division into its various parts, evincing the superior organisation of the nervous system. The eyes, in some cases, are provided with a "nictitating membrane," similar to that found in Birds, whilst the olfactory and auditory organs also exhibit an advance in the perfection of those senses, as observed in other divisions of the class.

The structure and physiology of their reproductive system also exemplifies the superior organisation of the *Elasmobranchii*. The generative organs are of large size, and exhibit a structure somewhat analogous to that found in the highest Vertebrate forms, whilst the ventral fins of the male are provided with special appendages, subserving the reproductive process, and to which the term "claspers" has been applied. The ova are not so numerous as those of other Fishes, the eggs being generally enclosed in coriaceous or leathery capsules—familiarly known to seaside visitors as "Mermaids' purses," "Sea-purses," and the like. Certain members of the group appear to exemplify the "viviparous" mode of reproduction—the young being attached to the parent by a vascular connection, analogous to that found in Mammals, and termed the "placenta." Lastly, the embryos appear to be furnished, in the majority of instances, with external branchiæ, of rudimentary description, and which give place, as development proceeds, to true internal gills—this peculiarity serving, in a very striking manner, to connect the *Elasmobranchii* with the next or higher class, that of the *Amphibia*. Viewed with regard to their palæontology, the present group of Fishes presents several interesting features; the order attaining a considerable development in geological epochs. The early appearances of these forms in Palæozoic strata are marked by the presence, in a fossil condition, of the dermal spines; these appendages being known to palæontologists as "ichthyodorulites."

The *Elasmobranchii* are divided into two sub-orders, the first of which—the *Holocephali*—is distinguished by the position of the mouth, which is situated at the extremity of the head; and by the single gill aperture. The most familiar representative of this sub-order is found in the *Chimæra*, more familiarly known as the "King of the Herrings."

The forms included in the second Sub-order—*Plagiostomi*—are distinguished by the transverse position of the mouth, which is situated on the under surface of the head; and by the numerous external gill openings, which, however, are not protected by an "operculum" or "gill-cover." The *Plagiostomi* are further subdivided into the following three sections:—

(*a*) *Cestraphori*, represented by the single genus *Cestracion Philippi*, or Port-Jackson Shark.

(b) *Selachii*, represented by the Sharks and Dogfishes, of which examples are depicted in Figure 102.

(c) *Batides*, represented by the Skates and Rays, (*Raiidæ*), and by the Sawfish (*Pristis antiquorum.*

Order 4. *Ganoidei.*—This order of Fishes is but sparsely represented by existing forms, and plentifully exemplified by extinct and fossil species. As implied by the name of the group, the nature of the exoskeleton forms a characteristic feature of these Fishes, the "ganoid" variety of scale being typically represented in the present instance. The character and structure of these scales, having already been alluded to, will not require further mention. The endoskeleton in the present order varies considerably in development throughout the group. Thus, in the Sturgeon (*Accipenser*), (Fig. 103, A), as representing one subdivision of the order, the "notochord" is persistent, and the skull cartilaginous. Others of the group, represented by *Polypterus* and *Lepidosteus* (Fig 103, B), have a fully ossified spinal column; the vertebræ in this latter form, and as previously noticed, exhibiting a divergence from the typical arrangement of these structures in Fishes, in that they are "opisthocœlous"—that is, convex in front and concave posteriorly. In the structure of the lower jaw, and also in the conformation of other parts of the endoskeleton, the Bony Pike exhibits a near affinity to the Amphibian or even Reptilian type of structure.

The "pectoral" (Fig. 103, *p p*) and "ventral" fins (*v v*) are invariably present; the latter members, as in the preceding group, being "abdominal" in position. The fin-rays, in the "paired" fins, spring from a common centre, formed by the endoskeleton of the fin, this "lobate" or "fringed" appearance of the "paired" fins (Fig. 103, B, *p*), forming, according to some authorities, a very characteristic feature of the group. The "dorsal" fin, in certain instances, is "multifid," that is divided into numerous portions, the anterior margins of each fin being provided with peculiar dermal scales, or more commonly spines, to which the term "fulcra" is applied. The "caudal" fin, whilst presenting in the majority of

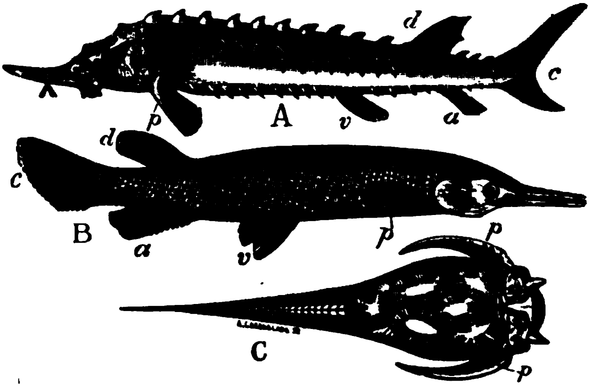


Fig. 103. Ganoidei.

A, Common Sturgeon (*Accipenser sturio*); *a*, anal fin; *c*, caudal fin; *d*, dorsal fin; *p*, one of the pectoral fins; *v*, one of the ventral fins. B, Bony Pike (*Lepidosteus osseus*), showing "lobate" arrangement of pectoral fins. C, *Pterichthys Milleri* (Old Red Sandstone), showing greatly developed pectoral fins (*p p*).

instances the "heterocercal" form, is also in some cases "homocercal."

The intestine in all Ganoid Fishes—with the single exception of the Lepidosteus—is provided with a well-developed spiral valve, similar to that described in the case of the Elasmobranchii (Fig. 99, B). The intestine, however, does not terminate in a "cloaca," but by a distinct anus: the urinary and generative organs terminating by a common orifice. The heart also bears a close structural relation to that of the preceding division, in that the "bulbus arteriosus" is contractile, provided with muscular fibres, and furnished with several rows of transverse valves. Respiration is performed, as in the typical Fishes, by true branchiæ or gills, supported upon "branchial arches," and enclosed in a special branchial chamber, covered by an "operculum." Supplementary branchiæ are in some instances borne by the inner surfaces of the "opercula," and in this situation "false" or "pseudo-branchiæ," receiving pure arterial blood only, are sometimes also found. As in many *Elasmobranchii*, "spiracles," or openings of tubes which communicate with the pharynx, and through which water can be admitted to the gills, are found on the dorsal aspect of the head.

An air-bladder is present in all Ganoid Fishes, this structure usually becoming "sacculated," or exhibiting a subdivision internally, into distinct cells. The swimming bladder, in the present instance, invariably communicates with the œsophagus by a distinct tube, termed the "pneumatic duct;" the homology of the sacculated air-bladder with the lung of higher forms, and of the "pueumatic duct" with the "trachea," or windpipe, will be at once apparent.

With regard to the geographical distribution of the Ganoid fishes, several interesting features are recorded, the chief of these being their limitation to the Northern Hemisphere; and secondly, their occurrence, in the majority of instances, in fresh-water seas and lakes; very few of these forms inhabiting the sea.

The order *Ganoidei* is divided into two sub-orders—the *Lepidoganoidei* and *Placoganoidei.* The *Lepidosteus,* or Bony Pike of North American lakes (Fig. 103, B), and the *Polypterus,* of the African rivers, are the most familiar forms included in this subdivision. The endoskeleton attains great perfection in the present instance, as also does the "ganoid" covering of the body, these forms being literally encased in a bony armour of great brilliancy. The "paired" fins are "lobate," and the "caudal" fin heterocercal. The *Dipterus macrolepidotus* (Fig. 104), the remains of which are of frequent occurrence in the Devonian rocks, exemplifies an extinct example of this sub-order. This latter form exhibited the ganoid armour in great perfection.

In the *Placoganoid* section of the order, the development of the exoskeleton, as well as of the endoskeleton, is not so perfect or complete as in the preceding division. The true ganoid "scales" of the *Lepidoganoidei* are replaced by detached "plates" of bony material, irregularly disposed over the body, and which, in the neighbourhood of the head, usually assume a large size, this latter feature being highly characteristic of many extinct forms also. The "paired" fins are not lobed, and the tail is generally "heterocercal" (Fig. 103, A).

The Sturgeons of Northern Europe (*Sturionidæ*) (Fig. 103, A), and the Paddle Fish (*Spatularia*) of North American waters, exemplify this latter section.

Of extinct Ganoid forms the majority belong to this latter subdivision; and of these the *Pterichthys* (Fig. 103, C), characterised by the great development of the "pectoral" fins (*p p*), and the *Cephalaspis*, in which the head was covered by a large "shield" or "buckler," are probably the most familiar forms. The *Ganoidei* attained the maximum of their development in the Devonian or Old Red Sandstone rocks of the Palæozoic epoch; the term "Age of Fishes" being applied, on this account, to the period of palæontological time corresponding to the deposition and formation of these rocks.

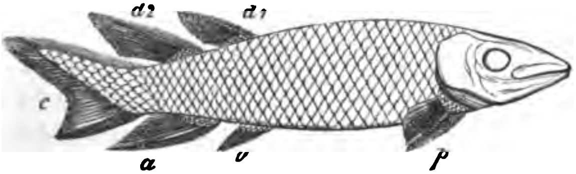


Fig. 104. GANOIDEI. *Dipterus macrolepidotus* (Old Red Sandstone); an extinct *Lepidoganoid* Fish.

a, Anal fin; *c*, heterocercal caudal fin; d^1, first dorsal fin; d^2, second dorsal fin; *p*, one of the pectoral fins; *v*, one of the ventral fins.

Order 5. *Teleostei.* — This order includes the great majority of ordinary Fishes, which, as implied by the term *Teleostei*, possess a more or less completely ossified endoskeleton. Any minute, or even general reference to the special morphology of the group will be unnecessary, the various points already noticed, when treating of the general structure of Fishes, corresponding in detail to the conformation of this, the most typical order of the class.

A brief *résumé* of the subdivisions of this extensive group, with their distinguishing characters, may therefore suffice in the present instance.

Sub-Order A. MALACOPTERI.—Fins complete; the rays "soft" or "jointed;" a swimming-bladder present, and provided with a "pneumatic duct" opening into the œsophagus; scales "cycloid," but in some cases "ganoid."

Sec. 1. *Apoda.* Ventral fins wanting.	Ex. Eels (*Murænidæ*). Electric Eel (*Gymnotus*).
Sec. 2. *Abdominalia.* Ventral fins present, these being "abdominal" in position.	Ex. Herrings (*Clupeidæ*). Salmon, etc. (*Salmonidæ*). Pikes (*Esocidæ*). Carps (*Cyprinidæ*), etc.

Sub-Order B. ANACANTHINI.—Fin-rays soft; "ventral" fins wanting, or if present, "jugular" or "thoracic" in position; swimming-bladder, when present, a shut sac.

Sec. 1. *Apoda.* Ventral fins wanting.	Ex. Sand-lance (*Ammodytes*).
Sec. 2. *Sub-brachiata.* Ventral fins present.	Ex. Cod, Ling, etc. (*Gadidæ*). (Fig. 98.) Flat-fishes (*Pleuronectidæ*).

Sub-Order C. ACANTHOPTERI.—First or anterior fin-rays of inflexible spiny consistence; "Ctenoid" scales; swimming-bladder a completely closed sac.

Sec. 1. *Pharyngognathi.* Ex. Wrasse (*Cyclolabridæ*).

Sec. 2. *Acanthopteri Veri.* { Ex. Perches (*Percidæ*). (Fig. 97.)
Mullet (*Mugilidæ*).
Mackerel (*Scomberidæ*), etc.

Sub-Order D. PLECTOGNATHI.—Bones of upper jaw and palate firmly ossified to skull; endoskeleton chiefly cartilaginous; ventral fins generally absent; ganoid scales; air-bladder closed.

Ex. Trunk Fishes (*Ostraciontidæ*).
File-Fishes (*Balistidæ*).
Globe-Fishes (*Gymnodontidæ*).

Sub-Order E. LOPHOBRANCHII.—Gills existing as tuft-like processes on "branchial arches;" endoskeleton cartilaginous; ganoid scales; swimming-bladder closed.

Ex. Sea-horses (*Hippocampidæ*).
Pipe-fishes (*Syngnathidæ*).

Order 6. *Dipnoi* (*Protopteri*).—This last order of fishes resembles the first group of the class, in that it contains but a single representative, and further resembles the *Amphioxus* in the anomalous nature of its position and relations. The *Lepidosiren* or Mud-fish (Fig. 105), found inhabiting the river Gambia, in Africa, and the Amazon in America, is the sole example of this order, which may be said to occupy somewhat of a transitional position, between the Fishes on the one hand, and *Amphibia* on the other.

The piscine characters of the Lepidosiren are found in its fish-like form; in the cycloid scales with which its body is covered; in the median fin which fringes the posterior extremity of its body; and in the possession of true gills, supported on "branchial arches," and contained within a special "branchial chamber," covered by an "operculum." The amphibian characteristics, on the contrary, are seen in the modification of the "pectoral" (*a*) and "ventral" fins (*b*), which exist as filiform jointed appendages, wanting but little additional change to convert them into rudimentary amphibian limbs; in the presence of lungs formed by the subdivision of the cellular air-bladder, which communicates with the pharynx by a distinct "trachea" or "windpipe;" in the three-chambered condition of the heart,—this organ now consisting of two auricles and a ventricle; and lastly, in the presence, in the young condition at least, of external branchiæ or gills.

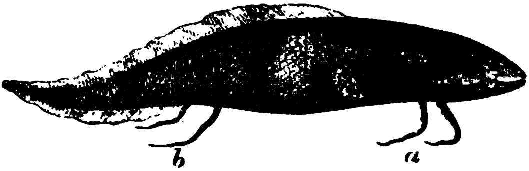


Fig. 105. DIPNOI.

Lepidosiren annectens, or Mud-fish; *a*, modified "pectoral" fins; *b*, "ventral" fins.

The endoskeleton is imperfectly developed, consisting of a persistent "notochord," possessing, however, traces of ossifications in its sheath. The intestine is provided with a spiral valve, and terminates in a "cloaca." The trilocular condition of the heart has been already noticed; an additional auricle (left), to which the aërated blood from the lungs is returned, being found in the present instance. The nasal sacs communicate posteriorly with the cavity of the mouth.

The habits of these singular creatures appear to be as curious as their structural relations. They inhabit the muddy banks of rivers, burying themselves in the mud during the dry season, and passing that period in a state of torpidity; to be recalled to active life by the return of the heavy and persistent rains which mark the advent of the wet season.

CHAPTER XXII.

VERTEBRATA.

PROVINCE A.—ICHTHYOPSIDA—(*Continued*).

CLASS II.—AMPHIBIA.

General Characters of Amphibia—Classification.

THE term *Amphibia*, applied to this class, indicates a prominent feature in the organisation of the forms included within its limits, the *Amphibia* forming, as it were, a connecting link between the aquatic and terrestrial Vertebrata, and being, accordingly, fitted for existence in both elements. Respiration, in the present instance, is performed at first, and in the early life of the Amphibian, exclusively by gills, but as the animal advances towards maturity, the gills in the majority of instances disappear, and the respiratory process is afterwards carried on solely by lungs. In other cases, however, the gills are retained, lungs being also developed; the co-existence of gills and lungs being thus characteristic of the more typical of Amphibian forms. Points of distinction from the preceding class are found in the fact that the "median" fins of Amphibia are in no case supported by fin-rays, whilst the limbs exhibit the same and typical parts of the endoskeleton found in the higher Vertebrata. The skull, in the present instance, articulates with the vertebral column by means of two articular prominences termed "condyles," this latter characteristic approaching of itself to the similar arrangement in the highest vertebrates; the *Mammalian* skull being also joined to the spinal column by two "condyles." The heart consists of three chambers—a ventricle and two auricles—another and left auricle being superadded to the more primitive and bilocular heart of the fish.

The nostrils open, in every case, posteriorly, into the pharnyx or cavity of the mouth; this arrangement contrasting with the shut condition of the nasal sacs in the Fishes. Lastly, the members of the present group undergo a more or less complete metamorphosis in their progress from the egg to the mature and adult form; this latter feature constituting one of the most important diagnostic characters of the class.

As remarked by Professor Huxley, "there is a striking contrast between the close affinity of the Fish and the Amphibian," the transition from class to class being accomplished by a series of gradual and transitionary stages, each of which is typified by a representative form. Thus, starting with the *Lepidosiren* or Mudfish (Fig. 105), which, as previously remarked, would appear to occupy an intermediate position between the two classes, we have a form partaking much of the piscine nature, but exhibiting several very salient Amphibian features also. Its form; the scales with which its body is covered; its fins; and above all, its branchiæ, contained in a true gill-chamber, covered by an "operculum," showing its undeniable relations with the previous class. But already we perceive Amphibian features beginning to be apparent; firstly, in the styliform fins, which exhibit a tendency to become rudimentary limbs; then in the "trilocular" or three-chambered heart; and lastly, in the differentiation of its "swimming-bladder" to form true lungs; and in other and peculiar features of its respiratory system, which have been already remarked. The curious *Axolotl* (Fig. 109, *b*), and still more remarkable *Proteus* (Fig. 109, *a*) or *Siren*, exemplify a further stage in the transition. The life of these creatures is essentially aquatic, and, accordingly, we now find external gills persistent through life; the lungs, although still rudimentary, having attained to a relatively greater development than in the preceding case. The Frogs, Toads, and Newts, introduce us to the final stage in the transition, in which forms we find external gills at first developed. These organs next give place to internal branchiæ, which latter, as development proceeds and as maturity is attained, wholly disappear, and give place to true lungs, the aquatic larva now becoming a true air-breathing form, and the change from an aquatic to a terrestrial type of structure being thus accomplished.

The integument is generally devoid of scales or other hard appendages, although in certain cases rudimentary structures of this nature are developed; these latter, however, never attaining the development observed in the preceding or succeeding classes. In most Amphibians the skin is supplied with numerous glands, secreting fluids of variable nature, and consistence; and in several forms, if not in all, the skin appears to aid materially the respiratory or breathing process.

In form, the generality of Amphibians are more or less fish-like, the resemblance to the preceding group being more particularly noticeable in their embryonic condition. In the higher Amphibians true limbs are developed, the body assuming a more or less stunted and shortened form. The limbs are entirely wanting in the *Cœciliadæ;* whilst only one pair,—the pectoral limbs,—exists in the *Siren.*

The endoskeleton (Fig. 106) exhibits great diversity in perfection of texture and arrangement. In some few instances the vertebral column exists as a "notochord," which, however, exhibits a decided advance on the similar structure of the preceding division, a fibrous sheath being developed, and depositions of bony material, representing the vertebral "centra" and "arches," being also found. A true bony skeleton, however, exists in the majority of forms, the vertebræ (Fig. 106, *a a*) being in some cases "amphicœlous" (Fig. 116, A), like those of the fish, but more commonly "opisthocœlous" (Fig. 116, C), that is convex in front and concave posteriorly; whilst in certain forms, exemplified by the *Anoura,* the vertebræ are "procœlous" (Fig. 116, B), or concave in front and convex posteriorly. The ribs appear to be, at most, rudimentary throughout the class; in the higher forms the place of these structures is supplied by the elongated transverse processes (Fig. 106, *a*) of the vertebræ. The skull in the lower Amphibia is of cartilaginous texture, but in the higher forms (Fig. 106) the cranial elements are completely ossified. The skull is articulated to the vertebral column by two "occipital condyles," an arrangement distinguishing the Amphibia from the *Sauropsida*, in which province only one "condyle" exists.

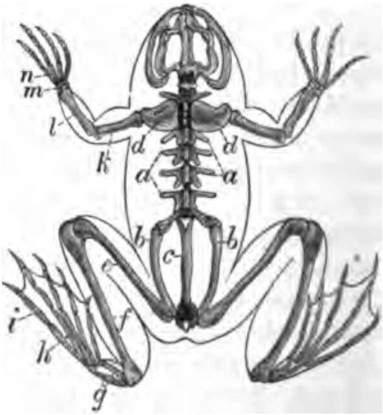


Fig. 106. OSTEOLOGY OF AMPHIBIA.

Skeleton of Common Frog (*Rana temporaria*); *a*, dorsal vertebræ, bearing greatly-developed transverse processes; *b b*, ilia, or side bones of pelvis; c, sacrum; *d*, scapula; *e*, femur; *f*, bone of leg (tibia and fibula); *g*, tarsus; *h*, metatarsus; *i*, phalanges; *k*, humerus; *l*, bone of arm (radius and ulna); *m*, carpus; *n*, phalanges.

The skeletal elements of the limbs are, in the higher forms, present in great perfection. As seen in the skeleton of the Frog (Fig. 106, *d*), a well-developed "scapula" or "shoulder-blade," "coracoid bone," and rudimentary "clavicle," are present. The "humerus" (*k*) is also distinct, but the "radius" and "ulna" are anchylosed or ossified together, so as to form a single bone (*l*). The six bones of the "carpus" or "wrist" (*m*), and those of the "metacarpus" and "phalanges" (*n*), are also to be readily recognised. The "pelvic arch" is present in tolerable completeness, and is composed of the elongated "sacrum" and "pelvic bones" (*b b c*). The "femur" or "thigh-bone" (*e*) is articulated to the posterior extremity of the "pelvis;" and, as in their prototypes of the upper limb, the "tibia and fibula" (*f*) are firmly united by ossification. The "tarsal" and "metatarsal" bones (*g h*) are also represented, the phalanges of the toes (*i*) being five in number, and elongated to afford attachment to the web or membrane of the foot. The digits of the pectoral limb (*n*) are only four in number, and are free and ununited by membrane; the superiority in size and length of the hinder limbs rendering these latter members the chief agents in the locomotion of these creatures. In the aquatic forms, represented by the Tritons and their allies, the limbs are developed to a much less extent than in the Frog, the flexible spine and persistent tail constituting the means whereby the movements of these creatures are effected.

The mouth of Amphibians is generally of large size, and in the majority of instances provided with numerous teeth, which in general become ossified to and united with the bones upon which they are borne. The alimentary canal is of very simple construction throughout the group. In several forms the tongue is undeveloped; in others it is fixed to the floor of the mouth; whilst in a third group it is of large size, and capable of being protruded to a great extent. The intestine terminates with the efferent ducts of the urinary and reproductive organs, in a common chamber or "cloaca." Salivary glands are wanting, but a capacious liver, spleen, and pancreas, are present in all.

The disposition of the hæmal and respiratory systems

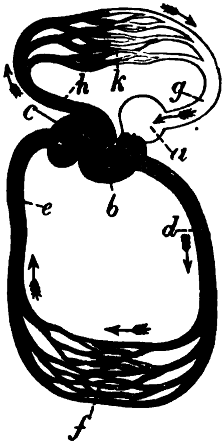


Fig. 107. Theory of Circulation in Amphibia and Reptilia.

a, Left auricle; b, common ventricle; c, right auricle; d, aorta carrying blood to the system; e, venæ cavæ, or great veins, returning venous blood to heart; f, systemic circulation; g, pulmonary vein bringing pure blood to left auricle; h, pulmonary artery carrying blood to respiratory organs; k, pulmonary circulation. The arrows indicate the current of the circulation. The purely venous blood is represented in black; the arterio-venous blood by the cross-shading; and the pure or arterial blood by the white.

in *Amphibia* is of somewhat complicated nature, since these systems vary greatly in arrangement and function at different periods in the life of the animal. Typically, the heart of the Amphibian, and that of the Reptile also, is "trilocular," or three-chambered, consisting of a ventricle (Fig. 107, *b*) and two auricles (*a c*); the separation of the auricles varying in completeness throughout the group. As depicted in Fig. 107, the right or "pulmonic" auricle (*c*) receives the venous blood from the body, whilst the left, or "systemic" auricle (*a*), is devoted to the reception of pure or arterial blood from the respiratory organs (*k*). The blood from these respective auricles is poured into the common ventricle (*b*), which latter chamber thus contains a mixture of arterial and venous blood. Of this impure blood, therefore, part is sent to the respiratory organs (*k*), whilst part is circulated through the body (*f*). This seeming imperfection in the circulatory processes of *Amphibia* and *Reptilia* may be accounted for in great measure—firstly, by the transitionary nature of these forms, the Amphibian heart foreshadowing the more perfect heart of the Bird and the Mammal; and, secondly, by the sluggish nature of the majority of these creatures, their slow movements and hybernating habits rendering unnecessary the more perfect circulation of higher forms.

With regard to the respiratory system in the present group, the gills attain a relatively larger size in those forms (*Perennibranchiata*) in which gills and lungs are co-existent; the latter organs again being in those cases of very rudimentary structure, existing for the most part as mere sacs, and differing only in the degree to which the perfection of internal segmentation, or division into cells, is carried. In the true air-breathing forms, however, in which the branchiæ of early life give place to lungs (*Caducibranchiata*), these latter organs assume a more perfect arrangement, the cellular structure becoming developed, and the general morphology of the lungs being at once perfected and defined.

The actual respiratory process in the lung-breathing Amphibia is, owing to the absence of true ribs, somewhat modified from the similar process in higher forms. The air necessary for respiration is accordingly taken into the lungs by a process more analogous to deglutition or swallowing than to the movements of ordinary respiration. The mouth is firstly shut, and air inspired through the nostrils, which apertures being in turn closed, the air is driven into the lungs. The skin, as previously mentioned, also assists in the respiration of these creatures.

The nervous system presents several striking phases of development, which correspond to the stages into which the early life of the typical Amphibian has been divided, and which also bear a close analogy to the nervous development of other and lower groups. Thus, the embryonic condition of the Amphibian brain presents a marked resemblance to that of the fish; whilst with the growth and succeeding development of the form, the nervous centres become better differentiated, and merge into a higher type of organisation. The brain and nervous centres of the lower Amphibia, such as *Proteus* and its allies, exhibit an inferior development to those of the higher forms; and partake more of the characters of the embryonic brain in the higher Amphibia, or of the adult nervous centres in the preceding class. The eyes in the lower members of the group are rudimentary, and concealed beneath the integument, as in the *Cæciliadæ* and *Proteus;* but in the Frogs and their allies the eyes are large, well developed, and possess a "nictitating membrane." The ears are in the Frogs of complicated structure, and communicate with the cavity of the throat. The nasal cavities in all cases communicate with the mouth.

The metamorphosis of the *Amphibia*, as exemplified in the case of the Frogs and Newts, forms the last feature in the general organisation of the group to which it is necessary to direct attention. Many Amphibians are "oviparous," but some appear to exemplify the "ovo-viviparous," or even the "viviparous" mode of reproduction. As observed in the Common Frog (*Rana temporaria*), the order of development proceeds in a very defined order. From the egg comes forth a curious fish-like form, familiarly known as a "Tadpole," furnished with a broad flattened head, and swimming actively by means of the elongated fish-like tail, with which it is provided. Soon after birth external gills (Fig. 108, *a*) begin to protrude from the branchial clefts, which shortly, however, give place to branchiæ situated internally (*b*), and supported, as in Fishes, on "branchial arches," which exist to the number of four. The heart, at the present stage, moreover, is essentially that of the fish, and consists of an auricle and a ventricle, occupied exclusively in driving the blood to the gills for aëration. As the "Tadpole" increases in size, the tail also grows more elongated, and the limbs now begin to be developed,—those of the hinder extremity being the first to appear in the case of the Frogs (*c d*), whilst in the Newts the fore-limbs are first developed. After the development of the limbs, the tail begins to decrease in size (*e*), gradually growing less and less, until it finally disappears (*f*); the basal portion of the "caudal" notochord alone remaining as a rudimentary appendage attached to the posterior portion of the spinal column, and termed the "urostyle." Lungs have meanwhile been developed, the heart receives an additional auricle, and is thus converted into the Amphibian type of structure; the

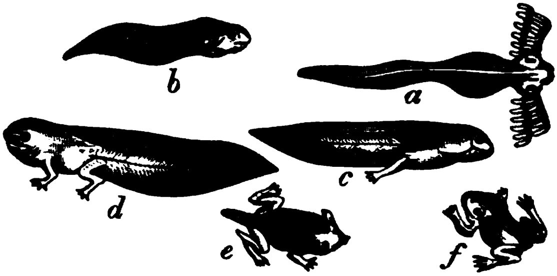


Fig. 108. METAMORPHOSIS OF AMPHIBIA. Development of Common Frog (*Rana temporaria*).

a, Young Tadpole, showing external gills; *b*, further development of *a*, with fish-like tail; the external gills have disappeared, and have been supplanted by internal branchiæ; *c*, advanced stage of *b*, in which the hind limbs have appeared; *d*, appearance of the fore-limbs; *e*, absorption of tail, and assumption of the mature form (*f*).

circulation accordingly alters to suit the new mode of life, the advent of which is marked by the Frog quitting the water, assuming the perfect form, and thus entering upon the new and final phase of its existence.

The various stages through which the Frog, in the progress of its development, passes, exemplify in a very remarkable manner the degrees of perfection observed in the morphology of various members of the group to which it belongs. The first stage of the metamorphosis, in which the "Tadpole" breathes by external gills, corresponds to the condition of adult life in the *Proteus* and its allies (Fig. 109); and when the external gills have disappeared, and the creature still retains its fish-like form, the mature condition of the *Tritons* or Newts (Fig. 110) is well exemplified.

CLASSIFICATION.—The Class Amphibia is divided into four Orders, the last of which is interesting in a geological sense only.

Order 1. *Ophiomorpha.* Ex. Cæcilia.
Order 2. *Urodela.* Ex. Triton, Proteus.
Order 3. *Anoura.* Ex. Rana.
Order 4. *Labyrinthodontia.* Ex. Labyrinthodon.

Order 1. *Ophiomorpha* (*Gymnophiona*).—This order includes a few snake-like forms, the proper place of which is still a matter of discussion. The *Cæciliæ*, worm-like animals, which usually attain a length of from one to two feet, and which inhabit the tropical regions of the world, typically exemplify this order.

They are of elongated serpentine shape, a circumstance from which the technical name of the order is derived, whilst, from the absence of limbs, the term *Apoda*, or "footless" Amphibians, occasionally applied to this order, is obtained.

The skin is soft, but possesses scales or other epidermal appendages imbedded in its substance. The vertebræ are "amphicœlous," and the eyes are small, and concealed beneath the integument.

The anal aperture is placed at the posterior extremity of the body. The lungs are rudimentary, and the presence of internal branchiæ in the young state would seem sufficiently to indicate their Amphibian nature. The *Cæciliadæ* inhabit damp, marshy spots, burrowing in the ground in search of grubs, etc., upon which they are supposed to subsist.

Order 2. *Urodela* (*Ichthyomorpha*).—The members of this group, typically represented by the Newts (*Tritonidæ*) and their allies, are distinguished by the elongated and persistent tail, which has procured for them the familiar term of "Tailed" Amphibians. The order is divided into two sections, according as the gills of early life are retained or not. In the first, or *Perennibranchiate* section, the external gills are retained throughout life, and of this group the *Proteus* (Fig. 109, *a*), representing the *Proteidæ*, and the *Siren*, representing the *Sirenidæ*, are probably the most familiar forms. The *Proteus* is only found inhabiting the waters of certain subterranean caves in Central Europe, the geographical distribution of this form being therefore of very limited area. It averages from twelve to fourteen inches in length, and is of a pale flesh colour, which contrasts forcibly with the scarlet colour of the external gills with which it is provided. The eyes are rudimentary; and the legs are also of feeble construction; the anterior limbs possessing three digits, and the posterior limbs only two.

The *Axolotl* (*Siredon pisciforme*), (Fig. 109, *b*), by some authors included in the *Sirenidæ*, and found inhabiting the Mexican lakes, possesses close structural relations with the *Proteus*. It attains a length of from ten to fifteen inches, the anterior limbs possessing four, and the posterior five toes. Whilst, ordinarily, the *Axolotl* is to be considered a *Perennibranchiate* form, it is also known to shed its gills, and thus become allied to the *Caducibranchiate Urodela*. In

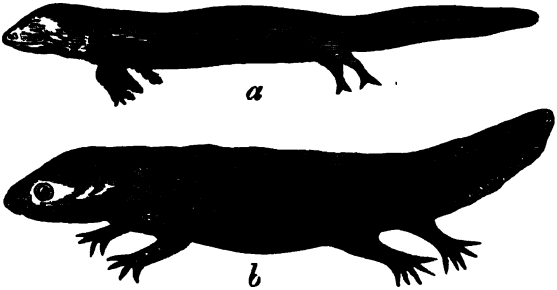


Fig. 109. PERENNIBRANCHIATA.
a, *Proteus anguinus*; *b*, Axolotl (*Siredon pisciforme*), also showing external persistent branchiæ or gills.

several other, but less familiar forms (*Amphiuma* and *Menopoma*), the gills disappear when the adult state is reached, but the branchial apertures never become obliterated.

The *Menobranchus*, an inhabitant of the North American lakes, possesses persistent branchiæ, and resembles the *Axolotl* in most particulars.

The *Sirenidæ*, forming the remaining division of the *Perennibranchiate* Amphibians, includes the various species of *Siren*, the most familiar of which is the *Siren lacertina*, or "Mud-eel," of the Carolina rice swamps. This form possesses only the anterior limbs, which are each furnished with four toes.

The *Caducibranchiata*, comprise those *Urodela*, in which the gills disappear when the perfect form is assumed. Of this section, the *Salamandridæ*, represented by the Land Newts, and the *Tritonidæ*, represented by the Water Newts or *Tritons*, are typical examples. The legs are always four in number, and

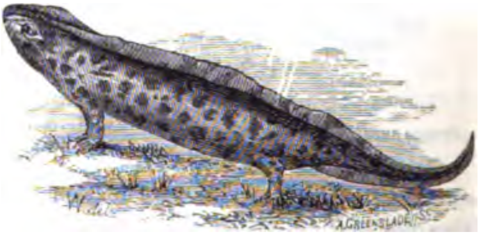


Fig. 110. CADUCCIBRANCHIATA.
Smooth Newt (*Lissotriton punctatus*), one of the *Tritonidæ* or Tritons.

exhibit a more perfect development than in the preceding section.

The Land Newts, or *Salamanders*, are lizard-like in form, possessing a rounded tail; they are also "viviparous," bringing forth their young alive. The Water Newts (*Tritonidæ*), (Fig. 110) are distinguished from their terrestrial neighbours by the compressed and fish-like form of the tail, which is furnished with a vertical crest or fin, aiding the creature in swimming. Of this family, the Smooth Newt (*Lissotriton punctatus*), (Fig. 110), a familiar inhabitant of our ponds and ditches, may be selected as a typical representative. The young in the *Tritonidæ* are produced from eggs, the Tritons being thus "oviparous." Their metamorphosis essentially resembles that of the Frogs, the material points of difference being the prior development of the fore limbs in the Newts, as also the persistent nature of the embryonic tail.

Order 3. *Anoura* (*Batrachia*).—The various kinds of Frogs and Toads represent this order, which is roughly distinguished by the abortive nature of the tail in the adult forms, a circumstance from which the technical name of the group has been derived. The only remaining general feature which may be noticed as characterising the "Tail-less" Amphibia, is the presence of gills in the larval or embryonic form; these structures giving place to true lungs, the respiration in the perfect animal being thus purely aerial.

The hind-limbs (Fig. 106) are developed to a much greater extent than the anterior members, the five digits of the posterior limbs being webbed for swimming. From the many marks of organisation, superior to that observed in the preceding groups, the *Anoura* must be accounted the highest of Amphibian forms.

The order admits of division into three families. Of these the *Pipidæ* are represented by the Surinam Toad (*Pipa Americana*), in which form neither teeth nor tongue exist. The *Bufonidæ* are exemplified by the Toads, in which a tongue is present, this organ being attached in front to the symphysis of the jaw, and capable of being protruded from the mouth. Teeth are absent in the *Bufonidæ* also. The *Ranidæ* or Frogs form the third and remaining group, and of these, the Common Frog (*Rana temporaria*), and the Tree-Frogs (*Hylides*), are typical representatives. The upper jaw in the *Ranidæ* is provided with teeth; and a tongue, similar in conformation to that of the Toads, is also present. The Tree-Frogs possess sucker-like dilatations on the extremities of the toes, these structures enabling them to climb trees with great facility. These latter forms are inhabitants of tropical climates, but their geographical distribution extends to Europe also.

Although it is well ascertained that Frogs and Toads can live for considerable periods without food, and with but a limited supply of air, the oft-repeated stories of these animals being found enclosed in apparently *solid* blocks of stone, and exhibiting on removal every appearance of life and activity, are not on that account to be credited or believed. Drs. Buckland, Edwards, and others, performed many series of experiments, with a view to ascertain the exact duration of life in these creatures when placed in circumstances of such adverse character as commonly described; and it was found that few of the specimens experimented upon lived over the first year, and that none survived the second year of their imprisonment. In addition to this positive evidence, and with our knowledge of the tenacity of life in these creatures, we must also take into important account the fact that these reports and stories generally take their origin from the credulous and uneducated. And even where instances meriting investigation have occurred, no scientific observer has been present to notify the details, the necessary destruction of the *habitat* preventing the observation of any channel whereby moisture or even nourishment could have penetrated to the imprisoned animal. Add to these, the possibility of the young larva gaining access to the hole, and becoming there developed into the perfect animal, the increased bulk of the latter preventing its exit by the aperture of entrance, and we have the necessary elements for the solution of what might otherwise, and justly, be considered a most inexplicable series of phenomena.

Order 4. *Labyrinthodontia.*—This order is interesting only from a palæontological point of view. It is typically represented by the *Labyrinthodon*, an extinct form, of gigantic dimensions, which departed from the

Amphibian characteristics in that the ventral surface of its body was protected by an armour-casing of dermal plates, whilst the head appears to have been similarly protected. The technical name of the group is derived from the complex or "labyrinthine" structure of the teeth.

The *Labyrinthodontia*, as real and entire organisms, were for a considerable period unknown, their homologies with the present group being traced solely from their footprints, which were at first known as those of the "*Cheirotherium*" or "hand-beast;" the discovery of distinct *Labyrinthodont* remains rendering the origin of these markings at once apparent.

The *Labyrinthodontia* occur as characteristic fossils in the Trias rocks, of the Mesozoic or "Middle-life" epoch of palæontologists.

CHAPTER XXIII.

VERTEBRATA.

PROVINCE B.—SAUROPSIDA.

CLASS III.—REPTILIA.

General Characters of Sauropsida—General Characters and Structure of Reptilia.

THE *Sauropsida*, forming the second of the great Vertebrate Provinces, include the two classes *Reptilia* or Reptiles, and *Aves* or Birds. Dissimilar as these two groups of animals would appear to be when viewed from an ordinary aspect, there nevertheless exist between them structural and developmental relations of the closest and most intimate kind; a careful consideration of the homologies of these classes inducing their arrangement under the common Province before us.

The first distinctive character of the Sauropsida, or, in other words, the first point of agreement between Birds and Reptiles, consists in the total absence of branchiæ or gills, these structures being present at no period of Sauropsidan existence; and the respiration being purely aerial, and carried on exclusively by lungs. In accordance with this important feature in the economy of the province, it will be seen that we now enter upon that section of the Vertebrata known in the older systems of classification as the *Abranchiata*. As in the preceding province the blood-corpuscles are nucleated (Fig. 94, B), and the skull articulates with the vertebral column by means of *one* occipital articulating process or "condyle."

The structure of the lower jaw in the Sauropsida affords an additional and important diagnostic feature of the group. In the *Mammalia* the lower jaw consists of two halves, or "rami," as they are technically termed, each "ramus" consisting of a single piece; but in the *Sauropsida*, each half of the lower jaw is composed of various pieces, the bone being thus of a compound nature. Further, the *Mammalian* lower jaw articulates directly, and of itself, with the skull, whilst in the *Sauropsida*, the lower jaw articulates with the cranium by means of a distinct and special bone, termed the "os quadratum" or "quadrate bone," (Fig. 113, A, *g*).

Lastly, the presence in the *Sauropsida* of the embryonic structures known as the "amnion" and "allantois," the existence of which structures was considered doubtful in the Ichthyopsida, constitutes another, but purely technical feature of the higher provinces of the Vertebrata. The "amnion" forms one of the true embryonic appendages of the "fœtus" or young animal; it more or less completely invests the body of the embryo whilst undergoing development, and is thrown off at birth. The "allantois" is more intimately connected with embryonic life, and appears to subserve wholly, or in greater part, the nutritive, but especially the respiratory processes of the embryo. After birth part of the "allantois" is also thrown off or exuviated, but part appears to be retained within the body of the young animal to form the urinary bladder.

The special distinctive features of the class *Reptilia* consist in the low temperature of the blood, these creatures being familiarly classed among the "cold-blooded" Vertebrata; in the "trilocular" or three-chambered condition of the heart; in the closed condition of the lungs as compared with those organs in Birds; in the character of the body-covering, this consisting in the present instance of horny plates or "scales;" and lastly, in certain peculiarities of the skeleton, to which attention will be more appropriately directed hereafter.

The *Reptilia* are generally of elongated form; the *Chelonia*, however, represented by the Turtles and Tortoises, form an exception to this rule, the body in this latter instance being oval or quadrate in form. The exoskeleton varies in development throughout the group; in some few forms the integument is naked, and destitute of any hard covering, but in the majority of instances horny plates, or scales, or osseous developments known as "scutes," are found. In the Snakes, as typifying the *Squamate* or scale-covered Reptilia, the exoskeleton consists of scales, which overlap each other in a manner similar to that observed in Fishes; whilst in the *Loricate* Reptilia, of which the Tortoises, Crocodiles, and allied forms offer typical examples, bony plates or ".scutes" are found, these structures being usually connected in a more or less intimate manner with the endoskeleton.

The endoskeleton is now of very complete construction, being composed in every case of true osseous tissue, and not exhibiting the variations in texture characteristic of the previous groups. The vertebral column varies greatly in length, and also differs in the mode of articulation of the vertebræ with each other. In some forms the "amphicœlous" or "bi-concave" arrangement of the vertebral bodies (Fig. 116, A), typically seen in fishes (Fig. 97, B), is found; in others the vertebræ are "opisthocœlous" (Fig. 116, C), whilst in others the "procœlous" arrangement (Fig. 116, B) is present. In some instances the vertebral column of a single form may itself exhibit these various modes of articulation. Thus, in the Green Turtle (*Chelone midas*), the third cervical vertebra is "opisthocœlous;" the fourth exhibits a bi-convex arrangement; and the fifth is "procœlous." Ribs are present in great perfection throughout the group, although it must be borne in mind that these organs are subject to great modifications. True "sternal" ribs, attached to and arising from the breastbone, are present in the most typical forms, whilst the sacrum may also bear "sacral" ribs.

The skull is composed of distinct cranial bones, intimately connected to each other by ossification, but the great bulk of the cranium consists of the jaws, the disposition and relations of which form interesting and important features in the economy of the class. The upper jaw is generally fixed to the cranium, but in some cases is connected to the skull by ligamentous tissue only. The lower jaw in all Reptilia exhibits a compound arrangement, each half or "ramus" consisting of a variable number of pieces, more or less firmly united together. The "rami" of the jaw are in turn usually connected together by ligamentous or muscular attachments; this arrangement permitting of that distension of the jaws necessary, as in the Snakes, for the reception of prey or food of large bulk. In certain forms, however, exemplified by the Tortoises, the rami of the lower jaw are firmly united by bony or osseous union, the point of union being technically known as a "suture." The lower jaw is articulated to the skull by means of a special bone, the "os quadratum," or "quadrate bone" (Fig. 113, A, *g*), an arrangement admitting of the opening of the mouth to a very wide extent.

The limbs are most highly developed in the Crocodiles, Turtles, and allied genera, but even in those higher members of the class, the limbs are of comparatively feeble and weak construction. In the *Ophidia* or Snakes, no trace of anterior extremities is found, whilst the pelvis generally, and hind limbs rarely, are represented by rudimentary structures.

Teeth are very generally present in the Reptilia, although in the *Chelonia* these organs are wanting, the jaws being encased in horny sheaths. When present, the teeth are usually numerous; and, save in the *Crocodilia*, are not lodged in distinct "alveoli" or sockets. Functionally regarded, the teeth of Reptiles bear little or no part as true masticatory organs, but serve on the contrary for the purpose of prehension, or for retaining the prey in the mouth, during the process of deglutition. A distinct tongue is usually present,—this organ in many cases being highly protrusible, and sometimes bifid or cleft at its free extremity. The œsophagus is generally exceedingly distensible, and the intestine terminates throughout the group in a "cloaca," in common with the ducts of the urinary and generative systems. Salivary glands are present in some instances, whilst a liver, spleen, pancreas, and kidneys, are well developed throughout the group.

The disposition of the typical Reptilian circulation is essentially similar to that already described in the case of the Amphibia (Fig. 107), the chief distinctive feature of which consisted in the mixing of arterial and venous blood in the common ventricle; the blood being thus circulated throughout the body in an arterio-venous condition. In the Crocodiles, however, an additional ventricle is found,—the heart in these forms being of perfect structure, and consisting of four chambers. The circulation of the blood, however, in the *Crocodilia*, is similar to that carried on in all other Reptiles; the arterial and venous blood in this case being mixed external to the heart itself, and in the great blood-vessels, instead of in the single ventricle of ordinary Reptilian forms.

Respiration is now performed entirely by lungs, which vary in size, and in perfection of structure throughout the class. The thorax is not partitioned off from the abdominal cavity as in the *Mammalia*, by a "diaphragm" or "midriff" (Fig. 92, *j*), and the lungs, consequently, occupy the greater part of the abdominal as well as of the thoracic cavity. In the Snakes typically, and in other members of the class, only one lung is developed to the full extent; the other lung—usually the left—being rudimentary, and not in any way subserving the respiratory process. In the *Chelonia*, the lungs reach their most perfect development, and closely resemble in all essential points, their homologues in the higher forms. The air necessary for respiration is inhaled into the lungs as in Amphibia, by a process analogous to deglutition or swallowing, although in some instances the muscular arrangements of the pharynx aid materially the respiratory function.

In the character and disposition of their nervous system, Reptiles bear a close resemblance to the Amphibia; the cerebral hemispheres and true brain, presenting, however, a marked advance on those of the preceding class. The eyes are small, and in general furnished with eyelids. In those genera, typically represented by the Snakes, in which no eyelids are ordinarily said to exist, homologous structures are developed; the so-called "antocular membrane" being in reality formed by the general epidermis or outer skin, rendered transparent, and otherwise fitted to perform the functions of true eyelids. In most instances, a "nictitating membrane," or "third eyelid," to be more particularly referred to in Birds, also exists.

Organs of hearing are present in all, but only in the

Crocodilia is an external ear present; this latter structure being, at best, of rudimentary construction. The nasal cavities in all open posteriorly into the mouth.

Although Reptiles are essentially "oviparous" animals, many members of this group exemplify the "ovoviviparous" mode of reproduction. In their development, the Reptilia exhibit a close resemblance to the next and higher class, with which, in many points of structure, they are, as previously noticed, closely allied. The presence of an "amnion" and "allantois" in the embryo, also affords a distinctive feature of great value in the differentiation of the reproductive process in these and allied forms.

CHAPTER XXIV.

Classification—Orders of Reptilia.

CLASSIFICATION.—The Reptilia, according to the most recent system of classification, are divided into nine orders, five of which, being represented by extinct forms only, will require but limited notice in the present instance.

Order 1. *Chelonia.* Ex. Turtles, etc.
Order 2. *Ophidia.* Ex. Snakes.
Order 3. *Lacertilia.* Ex. Lizards.
Order 4. *Crocodilia.* Ex. Crocodiles.

Order 1. *Chelonia.*—The *Chelonian* Reptiles, represented by Tortoises and Turtles, form a group separated from the other divisions of the class by several well-marked characteristics. The most obvious and striking of these features is found in the special development of the exoskeleton, which, together with certain portions of the endoskeleton, forms a more or less perfect bony "case," in which the body of the animal is enclosed, and to the structure of which it is necessary to direct particular attention.

The "thoracico-abdominal case" so formed consists primarily of an upper or dorsal convex shield, termed the "carapace" (Figs. 111 and 112), and of a lower or ventral plate, known as the "plastron." The "carapace" and "plastron" are united along their margins, except at the anterior and posterior edges, at which points the edges are free and ununited, to allow of the protrusion of the head and anterior members, and of the posterior members and tail.

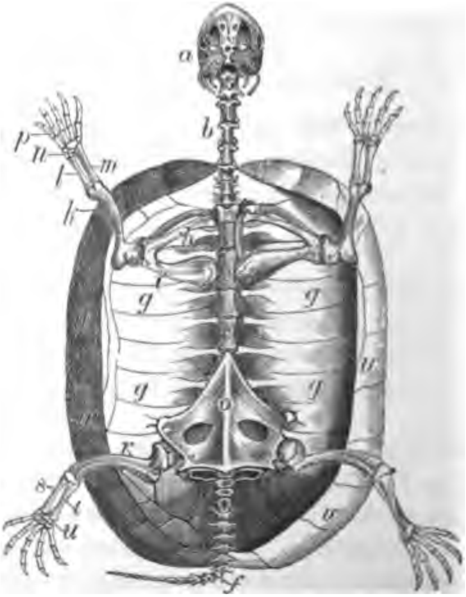


Fig. 111. OSTEOLOGY OF CHELONIA. Skeleton of Tortoise (*Testudo*), the "plastron" having been removed.

a, Skull; *b*, cervical vertebræ; *c*, dorsal vertebræ; *e*, sacrum; *f*, caudal vertebræ; *g g g g*, expanded and united ribs; *h*, scapula; *i*, coracoid bone; *k*, humerus; *l*, radius; *m*, ulna; *n*, bones of carpus; *o*, pelvis; *p*, phalanges; *r*, femur; *s*, tibia; *t*, fibula; *u*, tarsus; *w w*, marginal plates.

The "carapace" is formed chiefly by the eight pairs of ribs (Fig. 111, *g g g g*), which are greatly developed, to form broad flattened plates ("costal plates"), united to their neighbours of each side by their edges, and attached in the middle line to the expanded spinous or neural processes of the dorsal vertebræ (Fig. 112, s^1 to s^8). The dorsal vertebræ (Fig. 111, *c*) are thus immovably ossified together, their expanded spinous processes being known as "median" or "neural" plates (Fig. 112, s^1 to s^8). The carapace is further covered by a series of flat horny plates (Fig. 112, r^1 to r^8),

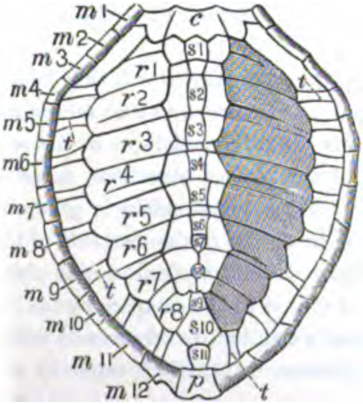


Fig. 112. **Morphology of Chelonian Carapace.** (Owen.)

c, Nuchal plate ; *p*, pygal plate ; *t t t t*, extremities of ribs ; m^1 to m^{12}, marginal plates ; r^1 to r^8, costal plates, overlying the expanded ribs ; s^1 to s^{11}, "median" or "neural plates," the first eight of which overlie the spines of the dorsal vertebræ. The costal plates of the right side are drawn in shading.

which properly belong to the exoskeleton; these dermal plates being more especially developed on the edges of the carapace, in which situation they are known as "marginal plates" (Fig. 111, *w w*, and Fig. 112, m^1 to m^{12}). By some authorities, however, the marginal plates are regarded as modified parts of the endoskeleton; these structures, in this view, being considered the homologues of the sternal ribs of other Reptiles, or of Birds.

Regarding the composition of the "plastron" or ventral shield, authorities are by no means well agreed; their opinions differing widely as to the relations and homologies of the various structures entering into its composition. This ventral shield is generally flat, and would appear to consist of the elements of the sternum or breast-bone. It is composed of nine plates, ossified together, and united to the carapace by the "marginal" plates previously mentioned. In common with the "carapace," the plastron is usually covered by a coriaceous or leathery membrane, or more generally by a series of epidermic plates (Fig. 112), those plates covering the carapace in certain species forming the "tortoise-shell" of commerce. In viewing the "plastron" of the *Chelonia*, as formed by the sternum or breast-bone, the views of Professor Owen have been adopted, but it is also necessary to mention that by Huxley, and other authorities, the plastron is considered as "wholly composed of membrane bones," which therefore bear no relation to the endoskeleton, but fall to be regarded as parts of the exoskeleton and integumentary system.

The existence of a sternum in *Chelonian* Reptiles is therefore denied by the last-mentioned author.

Anteriorly, the skull (Fig. 111, *a*), supported on movable cervical vertebræ (Fig. 111, *b*), is seen, the various pieces of the lower jaw in the *Chelonia* being firmly ossified together, and the compound character of the Reptilian jaw being masked by this circumstance. The two "rami," or halves of the lower jaw, are in the present instance also firmly united by bony union. The jaws throughout the group are destitute of teeth, but are enclosed in horny sheaths, thus resembling the conformation of these structures in the succeeding class of Birds. As already noticed, the dorsal vertebræ (Fig. 111, *c*) are firmly ossified together, and assist in the formation of the carapace. The caudal vertebræ (Fig. 111, *f*), like their prototypes of the cervical region, are flexible.

In the disposition of the "scapular" and "pelvic" arches, the *Chelonia* exhibit a somewhat anomalous arrangement, in that the bones of the shoulder-girdle (Fig. 111, *h*, *i*), and of the pelvis (*o*), are situated within the thorax, and thus enclosed by the ribs (*g g g*); the ordinary and usual position of these bones being external to the skeleton of the trunk (Fig. 91). The scapula (*h*) is readily recognised, and a coracoid bone (*i*) is also present. The clavicle by some authors is considered to be wanting throughout the group, whilst other opinions regard it as present. The pelvic arch (*o*) consists of the typical bones, and the skeleton of the limbs (Fig. 111) also exhibits the various elements in great perfection. The digits may either be free, and provided with short claws (Fig. 111), or, as in the case of the Turtles, they may be enclosed in a membrane to form natatory or swimming paddles.

The habits of the *Chelonia* are eminently inactive, many species passing the colder months of the year in a state of torpidity. They are, however, for the most part, exceedingly tenacious of life, instances being familiar, where Turtles have exhibited signs of vitality for several days after decapitation.

The Chelonia may be conveniently divided by their structure and habits into three sections. The first of these includes those forms which are adapted for a terrestrial existence, and in which the feet are provided with short blunt claws. The Tortoises (*Testudinea*) represent this group, which is further recognised by the convex character of the carapace, and by the power of retracting the head, limbs, and tail, wholly within the carapace. Of this section, the common European Tortoise (*Testudo Græca*) is a sufficiently familiar example. The second section includes the River and Marsh Tortoises (*Emydea*), and the Mud or Soft Tortoises (*Trionychoidea*). These forms are distinguished by the more or less imperfect development of the carapace, and by the partially-webbed nature of the feet; a feature indicative of the amphibious habits of the group.

The third group, that of the *Eureta* or Turtles, is distinguished by the webbed feet, the digits being completely united by integument. The anterior limbs are of greater relative length than the posterior, and the head and limbs are incapable of being retracted within the carapace, which latter structure varies in composition throughout the group. The Green Turtle (*Chelone midas*), and the Hawk's-bill Turtle (*Chelone imbricata*), are the two most familiar forms included in this section. From the epidermic plates of the latter form the "tortoise-shell" of commerce is derived. The Loggerhead Turtle (*C. caretta*), and the Leathery Turtle (*Sphargis coriacea*), distinguished by the coriaceous nature of the integument, are also well-known members of the group.

The geological relations of the *Chelonia* exhibit a few very interesting features. Traces of these Reptiles occur in the Palæozoic period; and in the Triassic rocks of India, the remains of a gigantic fossil form, allied to the Tortoises, and appropriately named the *Colossochelys Atlas*, have been found.

Order 2. *Ophidia.*—This order includes the numerous genera of Snakes and Serpents, in which the form is of characteristically elongated shape. The chief structural features of the *Ophidia* are found in the non-development of any osseous exoskeleton, the body being covered by horny scales; in the "procœlous" character of the dorsal vertebræ; in the complete absence of a sternum or breast-bone; of a pectoral arch and anterior limbs; and in the nearly general absence of hind limbs, which exist in a few species only, and at the most in a rudimentary condition.

The integument is covered by horny "scutes" or scales, the diversities presented by these appendages forming characters of no mean value in certain systems of classification of this extensive group. The epidermis or outer skin in the *Ophidia* is periodically cast off, the exuviated skin, in some cases, presenting a tolerably perfect mould or cast of the animal's body. This peculiar process, analogous to the so-called "moulting" of other animals, appears to take place at various periods in the course of the year.

The vertebræ, as might be expected, are exceedingly numerous, and typically present the "procœlous" arrangement (Fig. 116, B) of their bodies. The vertebræ give off short transverse processes, with which the ribs articulate. These latter structures are not attached inferiorly to a sternum; a true breast-bone, as already noticed, being absent throughout the group. The extremities of the ribs are thus free, and terminate in cartilaginous pieces, which in turn are imbedded in the muscular attachments of the large abdominal scales. By means of this arrangement the ribs become in a great degree subservient to the locomotion of these creatures; their bodies being supported, and the animal thus moving, upon the extremities of the ribs.

The skull exhibits certain features highly characteristic of the group. The more special of these features are found in the intimate structure and relations of the lower jaw, and in the disposition of the teeth. Thus, primarily, the compound "rami" or halves of the lower jaw (Fig. 113, A, *e e*) are not ossified together as in the *Chelonian* Reptiles, but are, on the contrary, exceedingly loosely articulated together; the rami being united by muscular or ligamentous attachments of great elasticity, and which consequently admit of great lateral distension of the jaw. Secondly, the "quadrate bone" (Fig. 113, A, *g*)—by means of which the lower jaw in the *Sauropsida* is articulated to the cranium,—is connected with the temporal bone, which in this case is exceedingly mobile; the entire maxillary apparatus in the *Ophidia* being thus less intimately connected than in other Vertebrates with the other parts of the skull. The mouth of these Reptiles is therefore capable of very great distension, admitting of the reception of prey, and objects of very large bulk.

In the disposition of their dental apparatus, the *Ophidia* also exhibit certain peculiarities. The teeth are generally of small size, and are not confined to the jaw-bones themselves, but may be borne upon the palatine and other bones, which form or bound the oral cavity. The teeth are not lodged in sockets, but become firmly united by ossification to the surface of the bones upon which they are borne, and, as in Fishes, they are replaced by a fresh set when worn or injured. Functionally regarded, the teeth of *Ophidia* are useless as masticatory organs, their sole function being the prehension and retention of prey, a duty for which, by their number, situation, and recurved form, they are eminently adapted.

Several modes of *Ophidian* classification have been founded on the relative number and position of the teeth, these organs exhibiting certain well-marked differences in conformation throughout the group. Thus, in the true non-venomous snakes (Fig. 113, A), the teeth are of solid construction, and are borne by both upper and lower jaws. In the typically poisonous snakes (*Viperina*), on the other hand, the upper maxillary, or jaw-bones, are destitute of ordinary teeth, but bear a pair of elongated, curved, and "canaliculated"

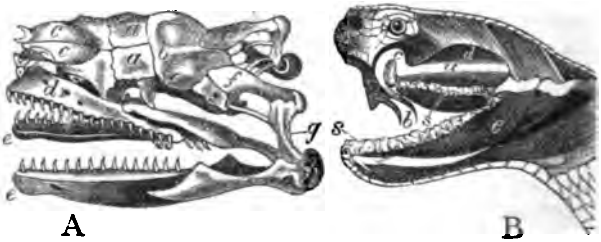


Fig. 113. OPHIDIA.

A, Skull of Boa. *a a*, frontal bones; *b*, parietal bones; *c c*, nasal bones: *d*, upper jaw, or maxillary bones: *e e*, halves of the lower jaw, or inferior maxillary bone; *f f*, mastoid bones; *g*, os quadratum. B, Dissection of Head of Rattlesnake (*Crotalus*), showing poison-gland (Duvernoy). *a*, poison-gland; *b*, poison-fangs; *c*, excretory duct, or canal of poison-gland; *d*, muscular capsule of gland, formed by the anterior temporal muscle; *e*, masseter muscle; *s s*, salivary glands.

or hollow fangs (Fig. 113, B, *b*), capable of being erected or depressed at the will of the animal. Each fang is perforated by a canal or duct (*c*), opening externally at the apex or point of the fang, and communicating internally with the poison-gland (*a*), situated in the posterior region of the head, and under the eyes. This gland is invested by a strong muscular capsule (*d*), formed by a diverticulum of the temporal muscle, the contraction of this capsule compressing the gland, and thus forcing the poison-fluid through the canal, into the fang, and thence into the wound caused by the bite of the snake. The lower jaw and palatine bones in these Snakes are plentifully furnished with ordinary teeth, as in the case of the non-venomous forms; whilst in the typically poisonous species, a number of rudimentary teeth are also found situated *behind* the poison-fangs, which they are intended to replace in event of injury. Such is the disposition of the dental apparatus in those Snakes, which, in the present system of classification, are regarded as the typically venomous species. It must, however, be clearly borne in mind, that in certain poisonous snakes, included in the second or *Colubrine* sub-order of the class, the upper jaws bear poison-fangs, which, however, are incapable of being erected or depressed as in the former group; and further, that ordinary and solid teeth are situated posterior to those fangs. In another group of the *Colubrine* Snakes, termed by some authors *Suspecta*, and in which, as implied by the name, the existence of a poison-apparatus has not been fully ascertained, true solid teeth are found, situated in front of or anterior to the fangs, which in the *Suspecta* are situated far back on the upper jaw. In accordance with these peculiarities, the order, as will be presently noticed, has been divided into subordinate divisions.

No trace of anterior limbs exists in any *Ophidian;* but in a few genera, typically represented by the Boas, rudimentary pelvic bones are present. In the genus *Tortrix*, allied to the Boas, abortive hind-limbs are present, in addition to the rudiments of a pelvis.

The tongue is generally bifid, or cleft at its free extremity, and capable of being protruded and retracted at will. Respiration is carried on by a single lung, the left lung being usually abortive, or of rudimentary construction. This unsymmetrical development of the respiratory organs appears to be repeated throughout the paired viscera generally; this feature being by some authorities regarded as highly characteristic of these forms.

The senses are present in tolerable perfection. The eye is destitute of true eyelids, but is protected by an "antocular membrane," similar to that alluded to in the case of the Amphibia.

The order *Ophidia* is divided into two sub-orders, known respectively as the *Viperina* and *Colubrina.* The characteristics of these two groups, in so far at least as the disposition of their dental apparatus is concerned, has been already noticed, but the diagnostic features of these sub-orders may, for the sake of clearness, be repeated in the present instance. The (a) *Viperina,* represented by the Vipers (*Viperidæ*) and Rattlesnakes (*Crotalidæ*), (Fig. 113, B), are distinguished by the presence of "canaliculated" poison-fangs, and by the absence of ordinary teeth in the upper jaw, the lower jaw bearing ordinary teeth. The head in the *Viperine* Snakes is of relatively larger size, of triangular shape, and covered by small scales. The Common Viper (*Pelias* *berus*) is a sufficiently familiar British Reptile, abounding in heaths and woody districts, and usually measuring from eighteen to twenty inches in length. The Rattlesnakes derive their scientific, and also their commonplace name from the peculiar arrangement of the terminal segments of the tail. These consist of a number of horny rings, loosely articulated together, and which produce a curious rattling noise on the slightest motion of the animal.

The (b) *Colubrina* are distinguished by the possession of solid teeth in both jaws; "canaliculated fangs" being present in the upper jaw in some instances also. The "fangs" of the *Colubrine* Snakes are further, as previously mentioned, not erectile, but are immovably fixed to the jaw. The head in this sub-order is supported on a distinct "neck," and the head-scales are of the larger variety, termed "scuta."

The *Colubrine* Snakes are divided into three sections. Of these the (a) *Innocua*, or Harmless Snakes, are represented by the Common British Snake (*Coluber natrix*); by the Black Snake of America (*Coluber constrictor*); and by the Boas and Pythons (*Boidæ*), (Fig. 113, A), of tropical climates. The *Innocua* are distinguished by the non-possession of "canaliculated" fangs. The (b) *Suspecta*, forming the second section, are represented by certain aquatic forms, in which canaliculated fangs are borne far back on the upper jaw, solid teeth being also situated in front of the fangs. The family *Homalopsidæ* includes the most familiar of these forms.

The (c) *Venenosa* include several of the most venomous of Snakes, and are distinguished by the possession of "canaliculated" fangs in the upper jaw, with solid teeth situated behind these organs. Of this latter group the Cobra di Capello, or Hooded Snake of India, (*Naja tripudians*), and the *Hydrophidæ* or Water Snakes, are representative forms.

The *Hydrophidæ* exist in the Indian and Pacific Oceans, and swim with great ease by means of the tail, which is compressed from side to side, so as to form an efficient natatory organ.

Order 3. *Lacertilia*.—The members of this group, familiarly known as Lizards, are distinguished by the more or less complete development of the limbs, which, in the great majority of instances, exist to the number of two pairs. In a few forms, however, the limbs may be absent, but in any case, the constant presence of a scapular, and generally of a pelvic arch also, forms a diagnostic feature of the present group, as compared with the *Ophidia*. The exoskeleton, whilst not exhibiting the characteristic appearances found in other Reptilia, is yet developed to a certain and appreciable extent, horny scales being very generally present in Lacertilian forms.

The relations of the lower jaw form, as in other Reptilia, valuable distinctive features of the order. The "rami" of the lower jaw in the *Lacertilia* are, in the majority of instances, firmly united by ossification, this mode of articulation alone forming a striking contrast to the analogous arrangement in the *Ophidia.* The teeth, which are not confined to the jaw-bones in their disposition, exhibit variations in form, adapting them to the particular food on which their possessors subsist. As in the previous orders of Reptiles, they are not lodged in "alveoli" or sockets, but become united by ossification to the bones on which they are borne, whilst they may be replaced when worn or injured by a new series.

The vertebral bodies exhibit for the most part the "procœlous" mode of articulation, although, in certain cases, the "amphicœlous" arrangement may also be observed. In the typical *Lacertilian* forms, a well-developed sternum is present, this structure bearing "sternal" ribs.

The structure of the tongue has been made use of in furnishing certain diagnostic characters of the various members of this group; this organ exhibiting great variations in form and appearance. In many cases it is elongated, bifid, and may be furnished with a horny sheath, from which it can be protruded, and into which it can be retracted at will (Fig. 115). Those Lacertilians exhibiting this style of lingual structure have accordingly been classified as the *Fissilinguia* or "cleft-tongued" Lizards. In other members of the group the tongue approaches to the ordinary type of structure, being thick and fleshy, and protrusible to a limited extent only. The forms possessing this latter conformation are occasionally known as the *Brevilinguia,* or "short-tongued" Lizards.

The eyes are usually provided with eyelids of the ordinary structure, the "antocular membrane," characteristic of preceding groups, being almost wholly wanting in the Lacertilia. An external ear is very generally present.

Of the numerous families included in this order, the (a) *Typhlopidæ* and (b) *Amphisbænidæ* approach most nearly to the *Ophidian* type of structure. These groups are collectively distinguished by their snake-like form, and by the imbricated scales with which the body is covered. The *Amphisbænidæ* are represented by the genus *Chirotes*, inhabiting Mexico, and in which rudimentary anterior limbs, furnished each with five digits, are found.

The (c) *Scincidæ* include, amongst other and numerous forms, the so-called "Slow-worms," of which the common British Slow-worm (*Anguis fragilis*) is a familiar example. As in the preceding groups, the Slow-worm exhibits a serpentiform appearance, the limbs being entirely wanting, but the scapular and pelvic arches being present. The Skink (*Scincus officinalis*), inhabiting Africa, and in former days famed for reputed medicinal properties, introduces us to the true Lizards, in which the limbs are developed, and the Lacertilian characteristics sufficiently apparent and perceptible. The (d) *Lacertidæ*, forming perhaps the most typical family of the order, are represented by numerous forms, of which the Common Sand Lizard (*Lacerta agilis*), the Scaly Lizard (*Zootoca vivipara*), and the Green Lizard (*L. Viridis*), are familiar European species. The *Ameividæ*, representing the New World members of this family, are represented by the well-known Teguexin (*Teius Teguexin*) of tropical America. The (e) *Varanidæ* or Monitors, inhabiting Egypt, attain a comparatively large size; they derive their familiar name from the sibillant or whistling noise with which they are supposed to indicate the presence of their more formidable Crocodilian neighbours. The (f) *Geckotidæ* or Geckos, found very generally distributed over the tropical regions of the world, form a very typical family, distinguished by the possession of an "antocular membrane," and by the sucker-like structure of the toes, which enables these Lizards to move on perpendicular surfaces with great ease and facility.

The (g) *Iguanidæ*, represented by the *Iguanas* of the New World, are also familiar forms. Included in this group we find the *Draco volans*, or Flying Dragon of the Eastern Archipelago (Fig. 114), which serves by its anomalous structure to connect certain extinct and aberrant Reptilian forms with those of the present day. The familiar name of this creature is derived from its habit of making short aerial flights, or leaps, from tree to tree. These movements are executed by the aid of broad lateral expansions of the integument (Fig. 114, *b b*), supported by eight pairs of false ribs; the entire structure thus forming a kind of parachute, which serves to buoy the creature in its flying leaps. The fossil form known as the *Pterodactyl* (Fig. 118), and to which reference will be more fully made hereafter, appears to possess analogous relations with this curious form.

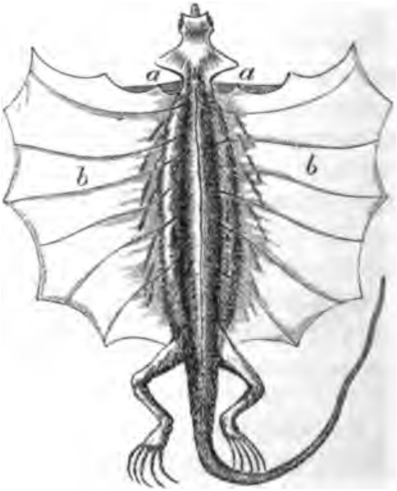


Fig. 114. IGUANIDÆ.
The Flying Lizard (*Draco volans*), showing the flying membranes (*b b*), and muscular apparatus for folding the same (*a a*).

The (h) *Chamæleontidæ* or Chameleons form the concluding family of this extensive order, to which attention may, in the present instance, be directed. These forms, inhabiting the Old World exclusively, have long formed objects of interest and curiosity. The structure of the tongue (Fig. 115), and the property by means of which the changes in colour are effected, form the two chief points of interest in the economy of these creatures. The tongue of the Chameleon

(Fig. 115) consists of a hollow muscular tube (*a*), capable of great and rapid extension, bearing a bulbous portion (*b*), which in turn is terminated by the true prehensile apparatus (*c d*). By means of this complicated arrangement, and aided also by the viscid secretion with which the bulbous terminal portion is covered, the Chameleon can lie concealed amid the branches of trees, and capture the insects on which it subsists with great facility. The power of changing the colour of of its skin has, by aid of the vivid imagination of travellers, been much exaggerated, although it has been well ascertained that the Chameleon undoubtedly possesses the power of altering its hue in some degree. This is effected by means of an arrangement analogous to that already described in the case of the *Cephalopoda*, namely, by the presence, under the superficial and transparent epidermis, of "chromatophora," or colour-cells, by the extension or depression of which, the changes of hue are effected.

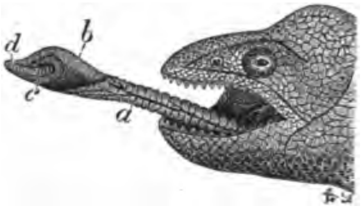


Fig. 115. LACERTILIA. Head and Tongue of Chameleon (*Chameleo Africanus*).
a, Tubular portion of tongue ; *b*, bulbous extremity of tongue ; *c*, *d*, prehensile apparatus.

In the Chameleons the eyes are completely covered by circular lids, through a small elliptical aperture in which the pupil of the eye is seen.

Order 4. *Crocodilia.* — The Crocodiles, forming the last and highest order of the present class, are distinguished from other Reptilian forms by several very distinct and special characteristics, these features being found in certain peculiarities of the osseous, digestive, circulatory, and nervous systems. The exoskeleton is very perfectly developed, and consists of bony "scutes" or plates, developed in the dermis or true skin; the "scutes" being in turn covered by epidermic scales of horny consistence, similar to those found in other Reptilia. This exoskeleton, in its most complete form, as exemplified by the *Caimans*, is disposed to form dorsal and ventral shields, which effectually protect the body and tail. The individual "scutes" of each row are firmly ossified to each other, whilst the rows of plates thus formed overlap the under rows in an imbricated manner. The exoskeleton of the *Crocodilia* thus bears some analogy to that of the *Chelonia*, although the endoskeleton, in the present instance, does not enter into the same intimate relations with the exoskeleton, as in *Chelonian* forms.

The endoskeleton exhibits a very high and perfect type of organisation; and, in accordance with the mode of articulation between the vertebral bodies, the *Crocodilia* have been conveniently divided into three groups. All living Crocodiles exemplify the "procœlous" arrangement (Fig. 116, B) of the vertebral bodies—that is, the vertebræ are concave anteriorly and convex posteriorly; a second type, represented solely by extinct forms, exhibited the "opisthocœlous" mode of articulation (Fig. 116, C), the concavity being in this case posterior, whilst the vertebral bodies were convex anteriorly; and a third type, or sub-order, exemplified the "amphicœlous," or bi-concave arrangement (Fig. 116, A),—the vertebral bodies being, in this latter case, hollow or concave at each end, and thus resembling the arrangement so characteristic of the Fishes. In other words, the "procœlous" and "opisthocœlous" modes of articulation are essentially "ball and socket" joints; the "ball" of each vertebral joint being situated behind in the "procœlous" vertebræ, and in front or anteriorly in the "opisthocœlous" forms.

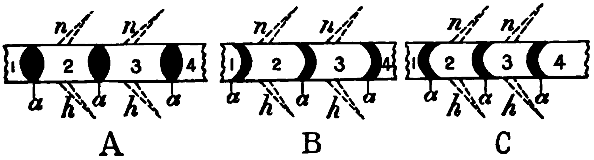


Fig. 116. Diagram of Vertebral Articulations.

The head of the animal is supposed to be turned towards the left hand side of the illustration.

A, "*Amphicœlous*" Vertebræ, showing the bi-concave arrangement of the vertebral bodies; *a*, intervertebral substance; *h*, hæmal spines; *n*, neural spines; 1, 2, 3, 4, bodies of Vertebræ.

B, "*Procœlous*" Vertebræ, showing the concave anterior and convex posterior surface.

C, "*Opisthocœlous*" Vertebræ, showing the convex anterior and concave posterior surface.

The various regions of the vertebral column are well marked, and the ribs are numerous; these structures being borne by the cervical, dorsal, and sacral vertebræ, and also by the sternum or breast-bone. "False" or "abdominal" ribs are also developed, these structures lying imbedded in the muscular tissues of the ventral or lower surface of the abdomen. The bones of the scapular and pelvic arches, and those of the limbs, are severally represented, but a clavicle is wanting throughout the group. The fore-limbs possess five digits, and the hind-limbs only four; the toes are frequently more or less completely united by a membrane, thus adapting the feet for swimming. The limbs in the *Crocodilia* are of comparatively feeble construction, the gait of these animals on land being exceedingly awkward and clumsy, although their movements in the water are characterised by great activity.

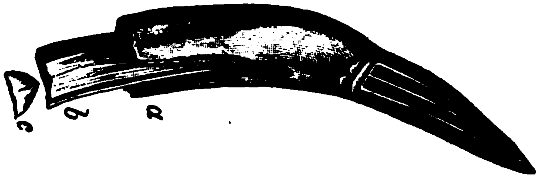


Fig. 117. CROCODILIA.

Teeth of the Gavial; *a*, fully formed tooth; *b*, young tooth penetrating the interior of the existing tooth (*a*); *c*, young tooth germ beginning to be developed.

The jaws are prominent and elongated, and are provided with a single row of teeth, which, unlike those of other Reptilia, are lodged in distinct sockets. New teeth are continually developed in the *Crocodilia*, the new tooth (Fig. 117, *b*) being formed within the interior or "pulp-cavity" of the organ (*a*) it is intended to replace. The halves of the lower jaw are firmly united together by ossification or "suture."

The tongue is firmly attached to the floor of the mouth, and is thus non-protrusible, a feature essentially different from the disposition of that organ in other Reptiles. The lungs are confined to the thoracic cavity, and a rudimentary diaphragm, separating the thorax from the abdomen, is present.

The principal structural feature, however, which places the Crocodilia in advance of other Reptiles, is the comparative homological perfection of the heart; this organ, in the *Crocodilia*, consisting of four chambers, and the common ventricle of other forms being now divided into two ventricles. The heart of the *Crocodilia*, therefore, consists of the same structural parts as that of the Bird or Mammal—namely, of two auricles and two ventricles. Functionally, however, and as previously remarked, the heart and circulation correspond to the ordinary Reptilian type, in that the pure or arterial blood from the lungs, and the venous blood from the body, are mixed in the great blood-vessels in the neighbourhood of the heart, instead of in the ventricle itself, as in all other Reptiles. The arterio-venous circulation of the Snake, Turtle, or Lizard, as exemplified in Fig. 107, therefore still prevails in Crocodilian forms.

The eyelids are of the ordinary type of structure, and the ear is also protected by a valvular membrane. The external nostril is single, and is also provided with a valve. The nasal passages open far back in the pharynx, and are thus shut off from the cavity of the mouth proper by osseous plates, derived from the jaw and palatine bones.

The Crocodilia are strictly oviparous in their habits, the eggs being deposited in sand, and hatched by the heat of the sun. The geological relations of the Crocodilia are bound up in the most intimate manner with the classification of the group; which, as previously observed, is divided into three sub-orders, the first of these alone being represented by living forms.

The (a) *Procœlia* include all the living Crocodilia, which are distinguished by the "procœlous" character of the dorsal vertebræ. This order is represented in the several regions of the world by three well-marked species. The Nilotic Crocodile (*Crocodilus Niloticus*), found in the African rivers, represents the true Crocodiles, the distinguishing features of this form being found in the fact, that the "fourth tooth in the lower jaw is received into a notch excavated in the side of the alveolar border of the upper jaw, and is visible externally when the mouth is closed" (Owen). The Gavial (*Gavialis Gangetica*), found exclusively in Indian rivers, is distinguished by the elongated jaws, which terminate in a snout, bearing the nostrils at its extremity. The teeth in the Gavial "are nearly equal in size, and similar in form in both jaws; and the first, as well as the fourth tooth in the lower jaw, passes into a groove in the margin of the upper jaw when the mouth is closed."

The Alligator (*Alligator Mississippensis*), found in American rivers, is the third and last representative species of *Procœlous* and living *Crocodilia.* The fourth or canine tooth of the lower jaw, in the Alligators, "is received into a cavity of the palatal surface of the upper jaw, where it is concealed when the mouth is shut." The genus *Caiman* is closely allied to the *Alligators.*

The *Procœlia* are of comparatively recent date as palæontological forms, the first appearance of these Crocodiles being found in the Cretaceous Rocks of North America, the typical fossil form being known as *Crocodilus bassifissus.* In Europe, the *Procœlia* first occur in the Eocene rocks of the Tertiary Epoch.

The (b) *Opisthocœlia* are represented exclusively by extinct forms, of which the most familiar is the *Cetiosaurus longus,* so named from its large and whale-like dimensions. The remains of *Opisthocœlous Crocodilia* are confined to the Mesozoic period. The (c) *Amphicœlia,* forming the concluding sub-order of the group, were most nearly allied in structure and habits to the existing *Gavials.* These forms were also confined to the Mesozoic period; and from the fish-like characters of their vertebræ, as well as from other modifications of the skeleton, would appear to have been more adapted than their existing prototypes for an aquatic existence. The most familiar *Amphicœlian* genera are *Teliosaurus, Steneosaurus,* and *Macrospondylus.*

Of fossil Reptilia, evidently belonging to types of structure irreconcilable with the characters of the existing orders of the class, the best known groups are the *Ichthyosauria*; *Plesiosauria*; *Dicynodontia*; *Ornithoscelida*; and *Pterosauria*.

The *Ichthyosauria* are typically represented by the *Ichthyosaurus*, the fossil remains of which are found in the Lias and Oolitic Strata of the Mesozoic period. The *Ichthyosaurus* possessed a fish-like form, and must have attained a considerable size. It appears to have united in the most intimate manner the relations of the Fish and the Lizard. The limbs were present in the form of swimming-paddles, and the existence of a caudal fin, similarly disposed to the analogous fin of Fishes, is now considered to be pretty accurately determined. The eyes were large and prominent, the eyeballs being protected by a special development of horny plates, situated in the sclerotic or outer coat of the eye; the entire structure of the visual organs eliciting from Dr. Buckland the opinion, "that the enormous eye of which they (the sclerotic plates) formed the front, was an optical instrument of varied and prodigious power, enabling the Ichthyosaurus to descry its prey at great or little distances, in the obscurity of night, and in the depths of the sea."

The *Plesiosaurus*, representing the *Plesiosauria*, resembled the preceding form in many respects, but differed from the *Ichthyosaurus* in possessing "a neck of enormous length." The limbs were in the form of swimming-paddles. The *Plesiosaurus* also attained a large size, and is supposed to have inhabited estuaries and the margins of rivers, lying concealed amid the reeds and flags which fringed the banks, and using the elongated neck to secure the fishes and other marine forms on which it preyed. The *Plesiosauria* are also exclusively Mesozoic.

The *Dicynodontia* and *Ornithoscelida* include forms of less familiar occurrence than the preceding groups. The *Dicynodon* typically represented the former group; the jaws in this form being provided with tusks, and the limbs suited for terrestrial progression. The *Ornithoscelida* are represented by the *Iguanodon* and *Megalosaurus*, two terrestrial forms of gigantic size, and by the *Compsognathus;* which latter, perhaps, more than the other forms, evinces in its structure a near approach to the Birds—a fact from which the technical name of the order has been derived.

The group *Pterosauria*, represented by the *Pterodactyl* (Fig. 118 A, B), includes a few forms which exhibit several curious and aberrant features in their organisation. The chief peculiarity in these forms consisted in the adaptation of the skeleton to flight, this adaptation being seen in the "pneumatic" character of the bones, in the arrangement of the pectoral arch, and in the elongation of the forearm (*e*) and fifth digit (5) to form an attachment for the "patagium" or flying-membrane.

The points of affinity to the structure of the Birds are found, firstly, in the conformation of the skull; the jaws, unlike those of Birds, however, being provided with teeth. The sternum also, as in Birds, bears a strong vertical median crest or keel, for the attachment of the pectoral or wing-muscles; and the interior of the long bones and vertebræ were filled with air, thus resembling the "pneumatic" bones of flying Birds. The pectoral limbs were modified to serve as organs of flight, the forearm (*e*) being elongated, and the fifth or outermost digit (5) being likewise greatly extended, to form a support for the "patagium" or flying-membrane, which, as depicted in the sketch of the living Ptero-dactyl (Fig. 118, B), was also attached to the sides of the body and to the hind-limbs (*g h i*). These latter members were of comparatively weak construction,

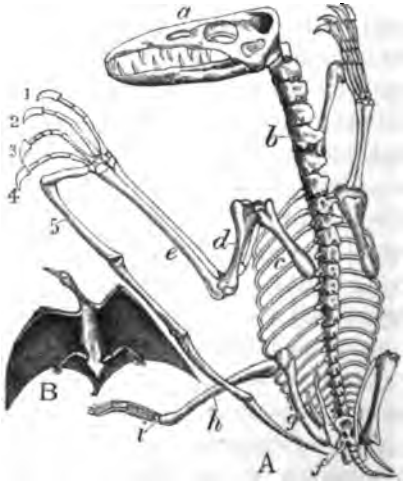


Fig. 118. PTEROSAURIA.

A, Pterodactyl (*Pterodactylus crassirostris*): *a*, skull; *b*, cervical vertebræ; *c*, coracoid bone; *d*, humerus; *e*, forearm; *f*, sacrum; *g*, thigh; *h*, bone of leg; *i*, digits; 1, 2, 3, 4, 5, digits of pectoral limb; the fifth or outermost digit being greatly elongated.

B, Sketch of living Pterodactyl, showing the disposition of the wing-membranes.

and apparently unadapted for ordinary terrestrial locomotion.

The structure of this curious Reptile calls forcibly to mind the analogous conformation of the *Draco volans* or Flying Lizard (Fig. 115), the structure of which has been already described, and which, indeed, may be considered the living prototype of this gigantic fossil form. The difference in structure, however, between the flying-membranes of these two forms will be at once apparent, and the powers of flight will also be seen to admit of very faint comparison, inasmuch as the flight of the *Draco volans* is at the best of a limited nature, whilst that of the *Pterodactyl* must have been very considerable. And although it may be doubted whether this old Lizard possessed powers of aerial locomotion equal to those of the Bird, yet it must have been capable of sustaining itself in the air in a manner similar to, or even more perfect than, that of the Bats, to which, in the disposition of its "patagium," it bears some resemblance.

The *Pterodactyl* and its *Pterosaurian* neighbours belonged exclusively to the Mesozoic period, which is thus characterised by the great development of Reptilian forms.

CHAPTER XXV.

VERTEBRATA.

PROVINCE B.—SAUROPSIDA—(*Continued*).

CLASS IV.—AVES.

General Characters and Structure of Aves—Habits of Birds.

THE class of *Aves* or Birds, whilst presenting many affinities to the Reptilian division of the *Sauropsida*, also exhibits a decided advance in structure, and approaches nearly to the *Mammalian* division of the subkingdom. The limits of the class under consideration are exceedingly well defined;—birds, from their peculiar conformation, the characteristic covering of the body, and their habits, presenting, even to the commonplace observer, features of unmistakable and certain identity.

The respiration is eminently aerial, and carried on by means of lungs, which exhibit a peculiar and highly characteristic arrangement of the bronchial or air tubes. The heart consists, in all Birds, of four chambers, and thus exhibits the same perfection of structure which characterises the circulatory organ of the *Mammalia*. The blood is of very high temperature, and the blood-corpuscles are nucleated (Fig. 94, B), and of oval shape. The remaining general features of the class may be summed up by observing that the skull articulates with the vertebral column by means of a single "condyle;" the fore-limbs are modified to form organs of flight; and the integument is covered by peculiar epidermic appendages known as "feathers." Lastly, Birds are eminently "oviparous," and the embryonic structures known as the "amnion" and "allantois," exist in this, as in the preceding group.

The form of the Bird, like that of the Fish, is admirably adapted for swift progression through the medium in which it lives; the entire structure of the animal being peculiarly modified to suit an aerial existence. This adaptation is seen not only in the covering of the body, as serving to preserve the necessary warmth, but also in the exceeding lightness of the bones, which, with the entire body, are permeated by air, thus rendering the creature light and buoyant, and recalling to mind the similar provision in the insect-economy, by which the body is lightened, and muscular exertion at the same time rendered less tiring.

The integument is covered with feathers, which are to be regarded as modified appendages of the outer skin or epidermis, and which "result from the conversion into horn of the cells of the outer layer of the "epidermis." A perfect feather consists of (*a*) the "calamus" or "quill," a hollow tube, inserted into the skin, and continued superiorly into the (*b*) "shaft" or "scapus," which forms the central stem of the feather. The (*c*) "web" or "vane" is composed of numerous "rami," "barbs," or fibres, which arise from each side of the shaft. The individual "barbs," of which the web is made up, are in turn furnished with smaller barbs termed "radii" or "barbules;" these latter serving to bind the web-fibres more closely and firmly together. The "shaft" at its inferior portion, where it merges into the "scapus" or "quill," is usually marked on its lower surface by a deep groove or "fossa," from which an accessory or supplementary "shaft" of small size, bearing a web, and termed the "hyporachis" or "plumule," takes its origin. The "plumule" is not, however, of general occurrence, being wanting on the "primary" or "quill" feathers of the wings and tail, and sometimes—as in the Ostrich and Apteryx—being absent altogether.

The principal modifications of feathers are "quills," "plumes," and "down." "Quill-feathers," having strong stiff shafts, are borne by the wings and tail only, and accordingly constitute the chief agents in flight. "Plumes" are of more slender make, of delicate texture, and constitute the general covering of the body. In the more typical "plumes," as seen in the Ostrich, the individual barbs of the web are free and unconnected; this open structure, together with their soft texture, constituting the well-known characteristics of these feathers. "Down," which forms the immediate covering of the body of most Birds, but more especially of the aquatic forms, consists of small feathers closely aggregated together; each "down-tuft" consisting of a short quill imbedded in the skin, and from which arises a number of filaments, destitute of a central stem, but provided with accessory filaments or "barbules."

The plumage of most Birds is preserved from the action of wet, and kept smooth and glossy, by aid of a peculiar unctuous or oily secretion, furnished by a special gland situated in the neighbourhood of the tail, and termed the "uropygium." The process of "preening," or dressing the feathers, by aid of this secretion, is familiar to all acquainted with the habits of aquatic Birds especially.

The variations in the form and functions of feathers have given rise to a special terminology, made use of by ornithologists in their systems of classification. Thus the feathers attached to the bones of the hand, and which are the largest of the wing, are accordingly termed "primaries;" those supported on the forearm "secondaries;" whilst to those arising from the upper arm, the name of "tertiaries" is applied. The quills borne by the attenuated thumb constitute an accessory pinion, termed the "alula" or "bastard wing." The feathers surrounding the ear have been also named "auriculars," whilst to those in the neighbourhood of the shoulder-girdle the term "scapulars" is applied. The "wing-coverts" are the series of feathers which cover the bases of the wing-quills, and also of the tail-feathers; the latter structures subserving the function of a rudder or steering-apparatus, and being appropriately known as the "rectrices." Those portions of integument usually destitute of feathers, such as the head, neck, and tarsi, are covered by epidermic scales; or the skin in the neighbourhood of the head and neck may be thrown into folds and wrinkles, known as "combs" and "wattles." Changes of colour, due to the presence of pigment cells and erectile tissue, are observed to take place in these structures—this feature being well seen in the case of several of our common and domestic fowls.

The endoskeleton of Birds exhibits many peculiarities in intimate composition, and in the structure and disposition of parts also. As regards chemical composition, the bones of Birds exhibit a greater preponderance of earthy salts than is found in the osseous tissue of Mammals; the salt known as phosphate of lime forming nearly 90 per cent of the earthy constituents in the present instance. The osseous material itself is also of more firm and compact description than in the highest Vertebrata, and in appearance the bones of Birds generally exhibit a characteristically white colour. The requisite lightness of the osseous material, which forms so important a provision in the economy of the present class, is at the same time, and consistently with the firm structure above alluded to, beautifully compensated for. The shafts of the long bones in most Birds, and in all which possess ordinary powers of flight, are accordingly filled with air instead of marrow, the term "pneumatic" being applied to the bones which exhibit this modification of structure. The air is admitted to the bones by special apertures in these structures; the necessary supply of air being furnished by the respiratory system, the consequent disposition of which (Fig. 123) forms one of the most peculiar features in the structure of Birds.

The perfection of this arrangement naturally corresponds to the size, habits, and ordinarily to the power of flight possessed by the various members of the class. Thus, in the Pelicans, Gannets, and Hornbills, the entire skeleton is permeated with air; and most of our common Birds exhibit this arrangement in a more or less perfect degree. In the Penguin, however, the habits of which are eminently aquatic, whilst its powers of flight are of the most limited description, and which may accordingly be selected as an example of the opposite extreme, the bones are filled, as in Mammals, with marrow; "the substitution of air," in this case, as remarked by Professor Owen, "would be rather a detriment than an advantage," since the body would in the latter case be rendered specifically lighter than the water, and progression be thus retarded. The Ostrich, however, exemplifies the observation of Professor Huxley, that "the amount of pneumaticity of the bones by no means follows the development of the powers of flight;" the bones in this latter form being "far more extensively pneumatic than in the Gull."

The vertebral column is divisible into the typical regions, but certain of its parts are subject to great modifications of the ordinary structural plan. The cervical segments are generally the most numerous, and are endowed with a considerable amount of flexibility; permitting of free movement in almost every direction. The use of this arrangement, in serving as a means of prehension, will be sufficiently obvious. The cervical vertebræ are never fewer than eight, whilst as many segments as twenty-three may be found, the Swans possessing this latter number. The dorsal vertebræ are more or less firmly united to each other; the union of these segments varying from one admitting of slight motion, as in Cursorial Birds, to a condition of immobility, produced by firm ossification or anchylosis. The dorsal region of Birds thus forms a compact mass, serving as a *point d'appui*, or fixed point of resistance for the movements of the wings. The lumbar region merges into the sacral portion of the vertebral column; these segments being ossified together, and forming a single bone termed the "sacrum." The caudal vertebræ (Fig. 121, B, *a*) are exceedingly mobile, the posterior segments of this region being ossified together, to form the "pygostyle," or "ploughshare" bone (Fig. 121, B, *b*), which affords firm attachment for the "tail-feathers," and also supports the "uropygium" or "oil-gland," previously alluded to.

The skull of Birds also exhibits a peculiar structure, inasmuch as the various bones of which it is composed are, in the early life of the animal, firmly ossified together, a complete and firm bony case being thus produced. The skull, as in the Reptilia, articulates with the vertebral column by means of a single occipital prominence or "condyle," and each half of the lower jaw, in accordance with the *Sauropsidan* characteristics, consists of a number of pieces, which, however, in the adult, are more or less completely anchylosed together. The lower jaw is articulated to the skull, as in the preceding class, by means of a separate bone, the "os quadratum."

The beak consists of the mandibles, formed by the elongated maxillary or jaw bones, and encased in horny sheaths, no true teeth being developed throughout the class. The form of the beak varies in accordance with the habits of the animal, and, together with the number and arrangement of the toes, is used as the basis for the ordinary classification of the group. The ribs, which vary in number with the dorsal segments, articulate with the bodies and transverse processes of these vertebræ. Each rib is connected with its posterior neighbour by a short process of bone, termed the "uncinate process," or "diverging appendage" (Fig. 89, B, *x x*). The ribs are attached in front by movable articulations to certain bones (Fig. 119, A, *e e*), springing from the sides of the sternum (*a*), and to which the term "sternal ribs" is applied. The sternal ribs correspond to the costal or rib cartilages in the higher Vertebrata (Fig. 91, *i*), and are themselves articulated to the sternum by movable joints, the adaptation of which to the respiratory movements of the chest will be readily perceptible. "False" or "cervical" ribs are found situated anteriorly on the cervical vertebræ; and the vertebræ of the post-dorsal region may also be provided with abortive ribs.

The most characteristic parts of the skeleton of the Bird, however, are the sternum or breast-bone, and the bones of the shoulder-girdle; the disposition of these structures exhibiting certain features of characteristic and special interest. The sternum (Fig. 119, A, *a*) is always of considerable length and breadth, and extends over the greater part of the anterior aspect of the body. Roughly speaking, the sternum is of a more or less quadrangular shape, concave on its ventral or internal surface, and provided on its outer or convex surface with a broad prominent ridge or keel (*a*), to which the great pectoral or wing muscles are attached. The development of the sternal keel must therefore bear a direct relation to the powers of flight of the bird; and, accordingly, we find that in those birds which possess considerable powers of flight, the keel is very broad, often equalling or exceeding in breadth that of the sternum itself. In the *Cursorial* or Running Birds, on the other hand, in which the wings are small, and used more after the fashion of oars or paddles to assist terrestrial progression, than as organs of true flight, the sternum exists as a broad convex shield (Fig. 119, B, *a*), entirely destitute of a ridge or keel. On its antero-superior aspect the sternum bears two articulating surfaces, which afford attachment to the "coracoid bones" (Fig. 119, A, B, *b b*), these latter structures forming the principal elements in the shoulder-girdle, which in the Bird is divisible into its three distinct and typical parts. The (a) coracoid bones (Fig. 119, *b b*) exist in the Mammalia generally, as mere processes of the scapula or shoulder-blade (Fig. 91, *c*); in this class, however, they attain a high and special development, being adapted to form "the main support to the wing, and the great point of resistance to the humeri, during the downward stroke of this aerial oar." The (b) "scapulæ" or shoulder-blades (Fig. 119, A, *d d*) are of elongated shape, and are attached by ligaments to the coracoid bones; whilst the (c) "clavicles" or collar-bones (*c c*) are united at their anterior extremities to

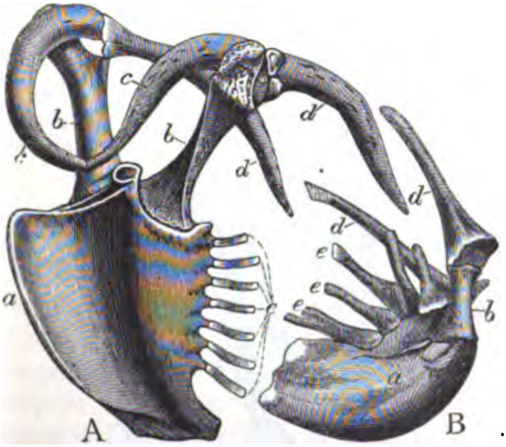


Fig. 119. Osteology of Aves.

A, Sternal apparatus of Golden Eagle (*Aquila chrysaëtos*); *a*, sternum and sternal keel; *b b*, coracoid bones; *c c*, clavicles, united to form the "furculum" or "merry-thought"; *d d*, scapulæ; *e e*, sternal ribs.
B, Sternum of Emeu (*Dromaius*). References as in previous figure.

form a single V-shaped bone, termed the "furculum," and popularly known as the "merry-thought." The "furculum" (*c c*) is articulated superiorly to the coracoid bones and scapula, and in most cases it is also attached by the united angle to the sternal keel.

The humerus (Fig. 120, *a*), which is generally of moderate length, articulates superiorly with a "glenoid" or "cup-shaped" cavity, formed by the scapula and coracoid bones; whilst inferiorly it presents articular surfaces for the bones of the fore-arm, of which the ulna (Fig. 120, *b*) is by far the largest. The radius (*c*) is also to be observed, this bone in some instances existing as a mere attenuated and rudimentary structure. The carpus or wrist (*e*) consists of three small bones, two of which form a wedge between the fore-arm and hand, and by thus limiting the movement of the wrist, give to the downward stroke of the wing the necessary firmness and support. The third carpal bone is attached to the metacarpus (*f*), which in reality is also formed by three bones, but apparently consists of two bones only; these two metacarpal bones (*f*) being united at their extremities. The fingers are represented by two digits (*i k*), which correspond to the second and

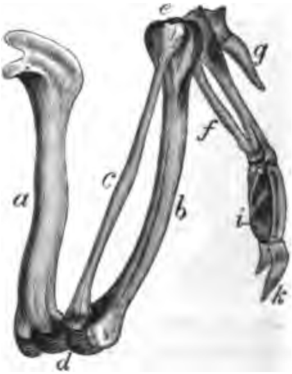


Fig. 120. OSTEOLOGY OF AVES.

Pectoral limb of the Jer-falcon (*Falco gyrfalco*); *a*, humerus; *b*, ulna; *c*, radius; *e*, carpal or wrist joint; *f*, metacarpus; *g*, thumb; *i k*, phalanges of fingers.

third fingers of the perfect and typical limb. Of these digits, the radial finger (*k*) is the larger, and consists of two or three phalanges; the ulnar finger (*i*) being composed in all cases of a single joint only. A rudimentary thumb (Fig. 120, *g*), consisting of a single joint, is also present; this structure being found attached to the outer side of the metacarpal bone (*f*), and serving to support the accessory pinion known as the "alula" or "bastard-wing." The terminal phalanges of the thumb and radial digit are usually provided with horny claws; this arrangement of parts, according to Huxley, constituting a characteristic feature of the class, since "in no existing bird does the terminal division of the fore-limb possess more than two digits terminated by claws."

The pelvis (Fig. 121, A, *a*), giving support and attachment to the hinder extremities, is distinctly developed, the halves of which it is composed being firmly attached to the lumbo-sacral vertebræ. In every case, with one solitary exception—that of the Ostrich—the halves or sides of the pelvis are ununited inferiorly, in the middle line; the pelvis, in other words, being open below. The femur or thigh-bone (Fig. 121, A, *b*) is short and stunted, and contrasts strongly in this respect with the elongated tibia (*c*), to which the fibula (*d*), existing, for the most part, like the radius in the wing, as an attenuated structure, is attached by ossification, or by fibro-cartilaginous tissue. A patella or "knee-cap" is also found in the majority of instances, this structure, more typically seen in the Mammalia (Fig. 91, *t*), serving to protect the knee-joint. The tarsus (Fig. 121, A, *e*) is composed of a single bone, to the lower end of which the metatarsus (*f*) is firmly united by bony union, the compound bone thus formed being known as the "tarso-metatarsal bone." (*e f*). In the *Grallatorial* or Wading Birds, the tarso-metatarsus is greatly elongated, and gives to these birds the great relative length of limb characteristic of the order.

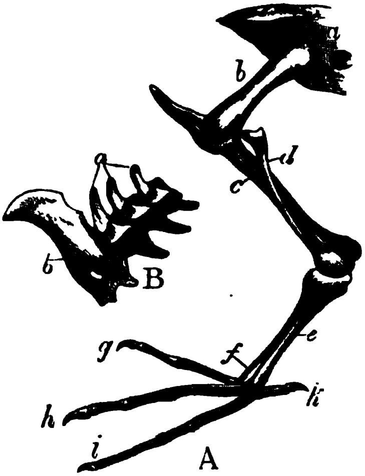


Fig. 121. OSTEOLOGY OF AVES.

A, Pelvic limb of the Loon (*Colymbus*). (Owen.) *a*, Pelvis; *b*, femur; *c*, tibia; *d*, fibula; *e f*, tarsus and metatarsus, forming, by their union, the "tarso-metatarsal" bone; *g h i*, front or anterior toes; *k*, hinder or great toe (*hallux*).

B, Caudal Vertebræ (*a*), and "pygostyle" or "plough-share bone" (*b*), of Golden Eagle (*Aquila chrysaëtos*).

The toes are generally four in number; three digits (*g h i*) being, in the great majority of instances, directed forwards,—the fourth (*k*), corresponding to the thumb or great toe (hallux), being directed backwards.

The number, structure, and arrangement of the toes, present so many and wide variations, that the characteristic features of each order have been drawn principally from the deviations in these organs. More extended allusion to the particular arrangement in each of the subordinate groups will be found under the head of "Classification," and a few of the more general features only need at present be noticed. The majority of Birds, therefore, possess four toes, the ordinary arrangement of these digits being, as above stated, three toes in front, and one toe situated posteriorly. In some forms, however, exemplified by the Bustards, the posterior toe is absent, whilst in the Ostrich (Fig. 125, *a*) only two toes are found. In the *Scansorial* or Climbing Birds (Fig. 126, *b*), represented by the Parrots, etc., the outermost toe is also directed backwards, the foot being thus rendered effective for grasping the boughs of trees; whilst in the Cuckoos, the outer toe can be turned either backwards or forwards at will. In the Swifts, Swallows, etc., the four toes are all turned forwards. By some authorities the posterior accessory claw or "spur," borne on the tarsus of many *Rasorial* or Scratching Birds (Fig. 125, *c*), exemplified by the Common Fowl, is accounted a distinct toe; accepting this view therefore, these birds must be regarded as possessing five digits.

In the aquatic species (Fig. 124, *b*) the toes are united by a web or membrane, the foot being thus converted into an efficient swimming-paddle. The disposition of this membrane varies considerably throughout the group, and its relations will be appropriately considered when treating of the *Natatorial* division of the class.

The toes are generally armed with claws or nails; the former appendages being seen in greatest perfection among the *Raptores* or Birds of Prey (Fig. 126, *d*), whilst the *Rasorial* Birds afford typical examples of forms possessing the latter structures.

The alimentary canal of Birds presents a marked advance in structural and functional perfection on that found in the preceding classes; certain modifications of the digestive apparatus, corresponding to the habits and food of the various members of the group, are also to be noticed in the consideration of the digestive tract. The "rostrum" or beak forms the chief agent in the prehension of food, the mandibles being also made subservient in a few instances to the tearing and subdividing, rather than the mastication, of nutrient matter. The mandibles may themselves be notched or serrated along their margins, but teeth are entirely wanting throughout the class. The tongue which, like the jaws, is in most instances enclosed in a horny sheath, cannot be said to act as a gustatory organ, although in many instances it subserves the function of prehension. Thus in the Woodpeckers, the tongue is armed at its tip with small recurved spines, and serves in the most effective manner to impale and capture the insects upon which the creature subsists. In the Toucans the tongue is almost similarly suited for prehensile purposes; and in the Humming-birds the horny sheath of the organ is further modified to form delicate filamentous processes, by means of which these creatures imbibe the juices of flowers. In the Parrots, on the other hand, the tongue is soft and fleshy, and in such cases the sense of taste is no doubt possessed in some degree at least.

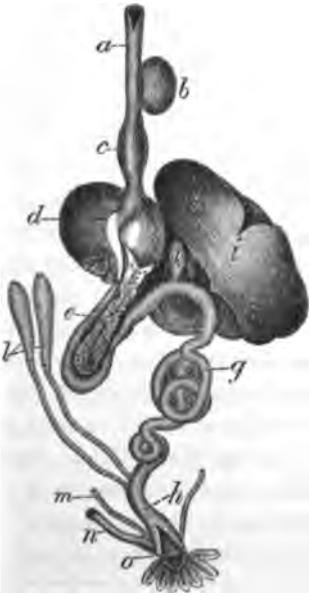


Fig. 122. Digestive System of Aves. Alimentary canal of Common Fowl.

a, Œsophagus; *b*, crop; *c*, proventriculus; *d*, gizzard; *e*, duodenum, or first part of small intestine; *f*, pancreas; *g*, small intestine; *h*, large intestine; *i*, liver; *k*, gall-bladder; *l*, cæcal appendages; *m*, ureter; *n*, oviduct; *o*, cloaca.

The œsophagus (Fig. 122, *a*) is generally elongated, capable of being greatly dilated, and presents in its course certain dilatations, to which attention must be particularly directed. The first of these, situated at the lower part of the neck, is termed the "ingluvies" or "crop" (*b*). This crop, which may be single or double, or—as will be hereafter explained—in certain cases wanting altogether, is a simple dilatation of the œsophageal walls, subserving the function of a storehouse or pouch, in which the food is for a time stored up, or in some slight degree prepared for the action of the true digestive organs. After leaving the crop the gullet expands into a second cavity (*c*), to which the term "proventriculus" or "ventriculus succenturiatus" is applied. The walls of this cavity—which is to be considered as the true digestive sac—are thickened, and contain numerous glands, which secrete the gastric juice; the food being subjected in the "proventriculus" to the solvent action of this fluid. Opening from the "proventriculus," and communicating freely with it, the third digestive cavity, or "gizzard" (*d*), is found; and in this latter sac, which is to be regarded as the "pyloric" or posterior portion of the stomach, the food undergoes further and important changes.

The structure and arrangement of these several cavities vary with the habits of the many and diverse forms included within the limits of the class. Thus, in those Birds which find their food constantly at hand—such as the Insectivorous and Fruit-eating species—no crop or other dilatations are found in the course of the œsophagus; the food in these forms passing at once and directly to the true digestive stomach. In the Carnivorous or *Raptorial* Birds, which do not feed with regularity, and whose habits do not allow of much time being spent over each meal, the crop (*b*) plays an important part in the digestive process; this cavity serving as a receptacle, in which the food, swallowed in greater quantity than can at once be digested, is stored. And in *Granivorous* Birds the "ingluvies" holds a still more important place. The crop in these latter forms is considerably enlarged, and subserves a preparatory digestive function, by pouring out on the contained nutriment a special secretion, the office of which is to soften it, and in all probability to further prepare it for the action of the other solvent and digestive juices. Generally, the crop consists of a single cavity. In the Pigeons it is double; whilst in Swans and Geese it is altogether absent.

The "proventriculus" (*c*) appears to preserve its character in a very constant manner throughout the group; the gastric follicles or glands secreting the gastric juice, however, differing widely in form, size, and situation. The gizzard (*d*) resembles the crop in the variations and modifications to which it is subject; these structural and functional differences being even more marked in this than in the previous case. The walls of the gizzard in Flesh-eating Birds are thin; the organ partaking more of the nature of a membranous sac, in accordance with the readily digestive nature of the food. But in the Grain-eating species, represented by the Common Fowl (Fig. 122), the walls are exceedingly thick and muscular; the gizzard (*d*) in such cases being converted into a kind of "crushing-mill," in which the hard husks of grain are triturated and bruised, and so rendered more susceptible to the action of the various solvent juices. The internal surface of the gizzard is thrown into numerous "rugæ" or folds, in which deposits of calcareous or horny matter are commonly found; these callosities, together with the stones, pebbles, and other hard substances swallowed by these Birds, serving, in the most effective manner, to grind and reduce the grain and vegetable matters upon which these forms subsist. Between these two extremes—the stomach of the Carnivorous Bird on the one hand, and that of the Granivorous Fowl on the other—there are many intermediate and transitional stages and arrangements; the nature of which, from their relations to one or both of these forms, will not be difficult to understand.

The intestinal canal (Fig. 122, *g*, *h*) in the Flesh-eating species is short, but of considerable length in the vegetable feeders. The division into the large and small intestine is marked sometimes by a valvular structure, but more commonly by the presence, at this point, of two "cæcal" or blind appendages (*l*), the exact function of which has yet to be determined. The intestine terminates in a cloaca (*o*), in common with the ducts of the urinary (*m*) and generative organs (*n*). A small sac, termed the "bursa Fabricii," the use of which is unknown, also opens into the upper part of the cloaca.

Salivary glands are well developed throughout the class, these organs existing in three distinct pairs. The "sublingual" salivary glands are subject occasionally, as in the Woodpeckers, to great development; the salivary secretion in these latter forms being of a viscid or gummy consistence, and serving to aid the capture of the insect-prey. The liver (Fig. 122, *i*) is well developed, and possesses a gall-bladder (*k*), the bile being conveyed into the intestine by two or three separate ducts. The pancreas (*f*) lies in a characteristic loop, formed by the "duodenum" (*e*), or first portion of the intestinal tract, the disposition of this organ corresponding with its arrangement in the *Mammalia*. The spleen is small, but the kidneys are of large size, the ureters (*m*) opening by two orifices into the cloaca (*o*). The renal function in Birds acquires an importance exceeding that of any other division of the Vertebrata; the nature of the body-covering, as preventing the ordinary work of excretion by the skin, necessitating the performance by the kidneys of the greater portion of the excretory function.

The heart and circulatory system of Birds is, to all intents and purposes, exactly similar to that of the *Mammalian* group which has been previously described (Fig. 95); the hæmal system of Birds being thus constructed upon the most perfect and typical plan. The essential features of the circulatory process consist in the double nature of the circulation, and in the complete separation of the two sides of the heart—a fact synonymous with the separation of the arterial from the venous circulation. The only remaining points worthy of notice are the strength and perfection of the valvular arrangements, and indeed of the whole heart, which is generally more muscular than in the other groups—a fact not to be wondered at, when the increased temperature of the body, and the great muscular exertion, involving a corresponding increase of tissue-waste, are borne in mind.

In the disposition of their respiratory organs, Birds exhibit certain features highly characteristic of the group. The lungs are large, and are attached to the vertebral column and ribs. The thorax or chest is not completely separated, as in the *Mammalia*, from the cavity of the abdomen by a perfect "diaphragm" or "midriff" (Fig. 92, *j*), the latter structure being present in a rudimentary condition only, throughout the class. The respiratory organs of Birds are usually of a light colour, and exhibit a more cellular texture than that perceived in the *Mammalian* lungs. They communicate with the pharynx, as in Mammals, by means of a "trachea" or "wind-pipe" (Figs. 92, *y*, and 123, *t*), the supporting rings of which are usually complete, and of fibro-cartilaginous or even bony texture. A "larynx" or organ of voice, termed from its position the upper or superior larynx, is situated at the upper extremity of the trachea, immediately behind the root of the tongue; whilst a second or inferior larynx, the true organ of voice in Birds, is found at the lower part of the windpipe, this latter structure being situated at the point at which the trachea bifurcates, or divides into two main air-tubes or "bronchi," each of which supplies a single lung with air. Each bronchus, after entering its lung, further subdivides into smaller and more minute branches (*b b*), the final terminations of these subdivisions being found in the minute air-vesicles or cells of the lung. The main trunks of the bronchi, however, open by distinct apertures (*a a a a*) on the surface of the lung, into certain sacs or cells termed "air-sacs," which exist in the thorax and abdomen of the Bird. These air-sacs, which generally exist to the number of nine, are formed by expansions and reflections of the lining membrane of the chest and abdomen; they communicate on the one hand with the lungs, and on the other by a system of passages with the interior

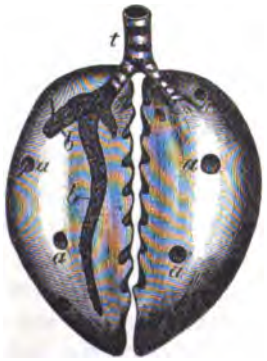


Fig. 123. Respiratory System of Aves.

Lungs of *Apteryx*. *a a a a*, Openings of bronchial tubes on surface of lungs; *b b*, bronchial tube opened (a bristle has been passed into the bronchus, and made to project through the external opening (*a*) of the tube); *t*, trachea.

of the "pneumatic" bones, the peculiar structure of which has already been described. The air inspired in the process of respiration, therefore, finds its way into every part of the body, including the skeleton, and thus subserves many and important uses, in addition to the due aeration of the blood.

The essential difference between the disposition of the respiratory apparatus in the Bird and Mammal will now be sufficiently apparent, and it is of the highest importance to bear this distinction constantly in mind. Thus, in the Mammal, the lungs (Fig. 92, *x*) are closed sacs, suspended in the thoracic cavity of the animal, which cavity in the Mammal is completely partitioned off from the abdomen by the perfect diaphragm (Fig. 92, *j*). The bronchi in the Mammal, further, do not open on the surface of the lung, but terminate in the air-sacs or cells in the interior of the organ; the inspired air, therefore, is confined to the lungs exclusively, and, save in case of accident or disease, does not find its way into any other part of the body. Contrasting this with the condition of parts in the Bird, essential and striking differences are apparent: the open terminations of the bronchi (Fig. 123, *a a a a*); the imperfect separation of the thoracic and abdominal cavities; and the distribution of air throughout the body, forming the chief characteristic points in the economy of the Bird.

The uses of this perfect and systemic distribution of air have been thus briefly summarised; firstly, the more perfect aeration of the blood; secondly, the maintenance of the necessary high rate of temperature; thirdly, the rendering of the whole body specifically lighter; fourthly, the mechanical assistance to muscular exertion, which is thus rendered less tiring; and fifthly, the enabling Birds to prolong their notes to a great length, and for a very considerable time.

The nervous system of Birds bears marks of increased specialisation; particularly of the chief centres of correlation. The cerebrum is relatively larger than in the preceding class, and the cerebellum or lesser brain is also to be recognised. The senses are, for the most part, present in very perfect array. The eyes are specially adapted to the particular wants of this sense in Birds; the shape of the lens, and also the presence of "sclerotic" plates, similar to those described in the case of certain extinct Reptilia, being among the chief structural peculiarities of the eye itself. A "nictitating membrane" or "third eyelid," is present, in addition to the ordinary eyelids. An external ear is deficient throughout the class, but an internal auditory organ of very perfect construction is found. The senses of taste and smell are, on the whole, but imperfectly developed; the tongue exercising more the function of a tactile than of a gustatory organ. The upper mandible appears also to subserve the tactile sense. The nasal cavities are of rudimentary construction, and terminate by openings usually placed towards the base of the bill. In the *Apteryx* the nostrils open at the free extremity of the mandible.

Birds are strictly "oviparous" animals. The ovaries and oviducts of the female are unsymmetrically developed, the organs of the right side being usually abortive. The calcareous shell is deposited round the impregnated ovum in the terminal portion of the oviduct (Fig. 122, *n*). The process of incubation, by which the eggs are hatched by the heat of the parents' body, reaches the acme of development and perfection in the present class.

In their habits, Birds exhibit many and striking differences. The Birds of temperate climates especially, remain, as a rule, constant inhabitants of their native countries; such forms being known as *Aves manentes*, or "permanent Birds." The migratory instinct, however, by which certain Birds leave a country on the approach of the colder season, flying over many hundred miles of sea and land in their journey to a warmer region, is among the most wonderful of the phases observed in the development of that faculty. Some birds wander from place to place without pursuing any definite course, their movements being guided principally by the plentifulness or scarcity of food, and to these forms the term *Aves erratici*, or "wandering Birds," is occasionally applied. Others—and of this latter group the Swallow and Cuckoo afford familiar examples—are true "migratorial Birds" (*Aves migratores*). These inhabit the northern regions of the world during the summer season, but leave with their young on the advent of autumn; flying southward to a more genial clime.

CHAPTER XXVI.

PROVINCE B.—SAUROPSIDA.

CLASS IV.—AVES—(*Continued*).

Classification of Aves.

THE ordinary, though artificial, system of classification of this extensive group, founded upon the differences observed in the structure and disposition of the beak and toes, and upon the consequent habits of the included forms, has the merit of being an exceedingly simple arrangement, if, at the same time, it be open to the objection that it is somewhat unphilosophical. The class *Aves* has therefore formed one of the debateable grounds of classification, numerous systems of arrangement having from time to time been constructed. Thus, according to certain authorities, the degree of perfection attained by the young Bird on leaving the egg was considered a suitable basis for dividing the class into primary sections; in the first of which,—the *Autophagi*,—the young Bird was born in a comparatively advanced state, and capable of providing for the wants of its own life; whilst in the *Heterophagi* the young were more or less dependent, after birth, upon the parents for support. Another method of classifying Birds was founded upon the particular spheres of existence inhabited by the various members of the class; and in accordance with this latter method, that of Nitzsch, Birds were divided into three groups, the "Aerial" Birds; "Land" Birds; and "Water" Birds. More scientific systems of classification have resorted to structural peculiarities in the members of the group, as bases of arrangement. By Huxley the Aves are divided into three groups, distinguished by the respective conformation of the sternum and tail. The first section, that of the *Carinatæ*, includes those Birds possessing sternal keels; this group, accordingly, embracing the vast majority of existing forms. The *Ratitæ*, forming the second section of Huxley, include those Birds in which the sternum is destitute of a keel (*Cursores*); the forms representing this group being as limited in number as those of the former division were extensive. The *Saururæ*, forming the last of Huxley's groups, embrace but a single and fossil form,—the *Archæopteryx*, the tail of which was "longer than the body," and destitute of a "ploughshare bone," whilst other peculiarities seem to indicate the affinity of this anomalous form to the Reptilian type of structure. The numerous subdivisions of the *Carinate* Birds, with the technical nature of the distinctive points, render this otherwise excellent system of classification unadapted for ordinary purposes.

The present and most universally accepted classification of *Aves*, divides the class into seven existing orders, distinguished, as previously observed, by their habits, and by the consequent differences observable in the beak and arrangement of the toes; and having due regard to the palæontological aspects of the class, an eighth order—the *Saururæ* of Huxley—is generally added to the existing seven.

The class *Aves* is accordingly divided, as follows, into eight orders:—

Order 1. *Natatores* (Swimmers). Ex. Penguin, Duck, etc.
Order 2. *Grallatores* (Waders). Ex. Snipe, Heron, etc.
Order 3. *Cursores* (Runners). Ex. Ostrich, Emeu, etc.
Order 4. *Rasores* (Scratchers). Ex. Grouse, Common Fowl, etc.
Order 5. *Scansores* (Climbers). Ex. Parrot, Woodpecker, etc.
Order 6. *Insessores* (Perchers). Ex. Shrike, Crow, etc.
Order 7. *Raptores* (Birds of Prey). Ex. Eagle, Owl, etc.
Order 8. *Saururæ* (Lizard-tailed). Ex. *Archæopteryx.*

Order 1. *Natatores* (*Palmipedes*), (Swimmers).—In this order, of which the Penguins (*Spheniscidæ*), Ducks (*Anatidæ*), Gulls (*Laridæ*), and other aquatic forms may be selected as representatives, the toes are more or less completely united by a web or membrane (Fig. 124, *b*), the foot being thus modified to form a swimming-paddle. In the majority of *Natatorial* Birds only three toes exist, these digits being directed forwards. In those cases in which the fourth toe or "hallux" is present, it is generally rudimentary, and is directed backwards, although in some instances the posterior toe is better developed, the web being continued backwards, and connected to this toe also (Fig. 124, *b*).

In some forms, exemplified by the Grebe (*Podicipina*), the web is modified, and unites the toes at their bases only, the remainder of the membrane being disposed to form broad lobes on the anterior part of the toes. The body in the *Natatores* is more or less boat-shaped, the legs being usually situated far back, and towards the posterior extremity of the body—a

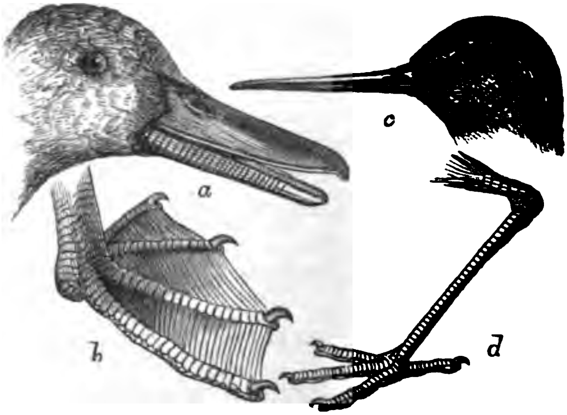


Fig. 124. NATATORES AND GRALLATORES.

a, Head of Common Mallard or wild Duck (*Anas Boschas*); *b*, foot of Common Cormorant (*Phalacrocorax carbo*); *c*, head of Wood Sandpiper (*Tolanus glareola*); *d*, leg and foot of Common Heron (*Ardea cinerea*).

position most favourable to their use in swimming, but which renders the gait of these birds exceedingly awkward and clumsy on land. The plumage is thick and downy, and is preserved from the action of the water, and also kept glossy, by the secretion of the "uropygium" or "tail-gland." The neck is generally elongated, enabling these Birds to procure their food by groping in the bottom of the waters they inhabit. The development of the wings varies throughout the group, and, in accordance with the relative perfection of these organs, the order has been divided by Professor Owen into certain subordinate divisions. In certain members of the order—chief of which the Penguin may be mentioned—the wings are quite rudimentary, and exist as mere fins or expansions of the integument, covered by a soft skin, furnished with scales instead of feathers. In the Frigate Bird (*Tachypetes*), on the other hand—a form well known for its amazing powers of flight—the wings are large and well developed. The Penguins are accordingly classified in the family *Brevipennatæ*, whilst the latter Birds are classified with the *Longipennate* forms.

The most familiar families of *Natatorial* Birds are the Penguins (*Spheniscidæ*); Puffins (*Fraterculidæ*); Auks (*Alcidæ*); Pelicans (*Pelicanidæ*); Divers (*Colymbidæ*; Gulls (*Laridæ*); Ducks (*Anatidæ*); and Geese (*Anserinæ*).

Order 2. *Grallatores* (Waders).—The *Wading* Birds, whilst possessing close relations with the preceding forms, present many characteristic and distinctive features. They are distinguished chiefly by the elongated "tarso-metatarsal" bones, which give to the legs their great length, enabling these Birds to wade in the shallow waters in which they find their food. The toes are generally four in number, three being directed forwards; and the fourth, varying in development, and being situated on the hinder or posterior aspect of the foot (Fig. 124, *d*). The feet are in no instance completely webbed, although in some cases, as in the Coots, the toes may be united at their bases by a short or abortive membrane. The neck is in most cases, and in accordance with the habits of the animal, greatly elongated, and the form of the beak also varies throughout the group. In those forms, exemplified by the Snipes, feeding on worms, insects, and food of similar description, the beak is long and of slender make (Fig. 124, *c*); whilst in the fish-eating species it is of shortened and stronger construction. The wings are generally of large size, and the legs, which in flight are extended behind the animal, supply the place of the tail; this latter appendage in these Birds being abortive, and incapable of serving as a rudder to guide their aerial flight. The order is represented by the Rails (*Rallidæ*); Coots (*Fulica*); Cranes (*Gruidæ*); Herons (*Ardeidæ*); Storks (*Ciconinæ*); Ibises (*Tantalinæ*); Snipes (*Scolopacidæ*); and Bustards (*Otidæ*).

Order 3. *Cursores (Ratitæ)*, (Runners).—The *Cursorial* or Running Birds form a very limited group, being represented in the present day by the Ostriches, Emeus, Cassowaries; by the Apteryx; and also by a few extinct forms. These Birds are for the most part of large size, and their organisation is specially modified to suit the change in life and habits. The pneumaticity of the bones, whilst still present, and in the Ostrich exhibiting a high degree of perfection, is on the whole also modified in accordance with the terrestrial nature of the progression in these forms. The sternal keel, so marked a characteristic of other forms, has now disappeared (Fig. 119, B), leaving the sternum as a flattened convex shield, from which character Huxley's term *Ratitæ* has been derived. The wings, in accordance with the general modification of type, are of comparatively feeble construction, being used after the fashion of aerial paddles, to accelerate the running powers of these Birds. The legs, however, are now strong and well adapted for running, the muscular development of the pelvic limbs now assuming a higher and more perfect phase of development. The anterior toes exist to the number of two, as in the Ostrich (Fig. 125, *a*), or three, as in the Emeu and allied forms; the hinder or posterior toe being absent, save in one instance, that of the *Apteryx*, in which a rudimentary hinder toe is found. The barbs composing the webs of the feathers are more widely separated than in other instances, and present a close resemblance to hairs, thus giving the plumage a very peculiar and characteristic appearance. The beak is generally short and compressed, the neck, however, being greatly elongated.

The order contains two families, the first of which, that of the *Struthionidæ*, is represented by the Ostriches, in which the hinder toe is absent. The African Ostrich

(*Struthio camelus*); the American Ostrich (*Rhea*); the Emeu (*Dromaius*), inhabiting New Holland; and the Cassowary (*Casuarius*) of the Eastern Archipelago, are the representatives of the first section.

The second family (*Apterygidæ*) is represented by the *Apteryx*, or wingless Bird of New Zealand, which is distinguished by its elongated slender bill, by the shortness of the legs, and by the very rudimentary and abortive nature of the wings. A small hinder toe or "hallux," provided with a claw, is present in the *Apteryx*. Little is known respecting these singular Birds, save that their habits appear to be principally nocturnal, their food consisting of worms and insects.

The fossil remains of the *Dinornis*, a gigantic wingless form, occurring in the superficial deposits of New Zealand, and related in structure to the *Apteryx*, have been referred to this order, which, no less in its palæontological than in its ordinary aspects, exhibits many interesting and anomalous features. The remains of two extinct species of *Apteryx* are found associated with the *Dinornis* fossils; the latter form having been thus, in all probability, contemporaneous with the existing Apteryx. The fact of the remains of the *Dinornis* being found in the most superficial formations, and under other and equally important circumstances, justifies the belief that the *Dinornis*, or its allies, may still be in existence in the less accessible and unexplored parts of these islands.

Order 4. *Rasores* (*Gallinacei*), (Scratchers).—The body in this group is generally short, the neck being of moderate length. The beak (Fig. 125, *b*) is of ordinary size, but of strong construction, the upper mandible projecting more or less completely over the lower one. The legs are shortened, and are in many cases covered with feathers, even to the tarsi and toes. The three front or anterior toes are well developed, the hinder toe being generally of small size, and elevated on the posterior aspect of the tarsus (Fig. 125, *c*), which also bears, in the majority of instances, one or two spurs, constituting powerful weapons of attack or defence. The toes are armed with short, blunt nails, suited for scratching the ground in search of the grain and seeds upon which these birds subsist. The wings are generally of weak construction; the plumage, however, exhibiting in most instances great brilliancy of colour.

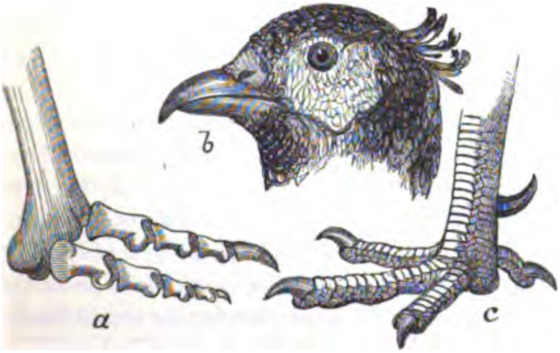


Fig. 125. Cursores and Rasores.

a, Skeleton of foot of Ostrich (*Struthio camelus*), showing the two toes; *b*, head of Common Pheasant (*Phasianus Colchicus*); *c*, foot of Domestic Turkey (*Meleagris gallopavo*), showing the tarsal "spur."

These forms, exemplifying the typical Granivorous or Grain-eating Birds, accordingly exhibit in highest perfection the form of digestive apparatus specially adapted for such a diet. The structure of such an alimentary tract has already been described (Fig. 122); the chief points to which attention need here be directed being the large size of the crop, together with the muscularity and development of the gizzard. The young typically exemplify the *Autophagous* section of the class, in that they are, immediately after birth, comparatively independent of the parents' care and support.

The order is divided into two sections or sub-orders, in the first of which, that of the (*a*) *Gallinacei*, all our domestic Fowls are included. Of this group the most important families are, firstly, the *Tetraonidæ*, represented by the Grouse (*Tetrao*); Ptarmigan (*Lagopus*); Partridges (*Perdix*); and Quails (*Coturnix*); and secondly, the *Phasianidæ* or Pheasants, forming the second family, and including the Pheasants (*Phasianus*); Turkeys (*Meleagris*); the Common Fowl (*Gallus*), and other familiar forms. The (*b*) *Columbacei* or Doves, forming the remaining sub-order, possess powerful wings, and have the hinder toe, as well as the anterior toes, well developed. The ordinary Pigeons (*Columbidæ*); the Ground Pigeons (*Gouridæ*); and Tree Pigeons (*Treronidæ*), exemplify this latter group, which also includes a singular creature named the *Dodo*, and which is classified in a special family, that of the *Dididæ*. The *Dodo* was a bird of large size, which inhabited the island of Mauritius towards the close of the sixteenth century, after which period it was extirpated by the hand of man, our knowledge of its structure and habits being obtained from detached remains, from paintings, and also from contemporaneous literature. The *Dodo* was a bird of heavy appearance and clumsy gait, the wings being rudimentary, and the feet of short stunted description. The feet presented *Rasorial* characters, although, from its general conformation, some authorities would incline to classify it with the *Cursorial* Birds. A companion example to the *Dodo*, of extermination by the hand of man, is found in the case of the *Solitaire*, a form which once inhabited the neighbouring island of Rodriguez, and which, from the description of voyagers and travellers, would appear to have resembled the *Dodo*. Like the latter form, the work of extermination has grouped the *Solitaire* with non-existing species; the deficiency in the powers of flight ensuring the ultimate and easy destruction of these and allied forms.

Order 5. *Scansores* (Climbers).—The members of this group are distinguished by the disposition of the four toes, which are directed—two forwards and two backwards (Fig. 126, *b*), an arrangement enabling these Birds to grasp objects with great facility, and thus assist them materially in climbing. The outermost of the ordinary front toes is, by this arrangement, therefore turned backwards, to form, with the posterior great toe, opposing digits to the two remaining and front toes. The beak is formed upon one or other of two distinct types. In the first of these, exemplified by the Parrots (Fig. 126, *a*), the upper mandible is hooked and projecting, and thus forms a powerful instrument in the pseudo-mastication of fruit and seeds, upon which these and allied forms subsist. In other forms, which feed upon insects, such as the Cuckoos and Woodpeckers, the beak is slender and elongated, the extremity being in some instances truncated, or in other cases pointed, and furnished with toothed projections.

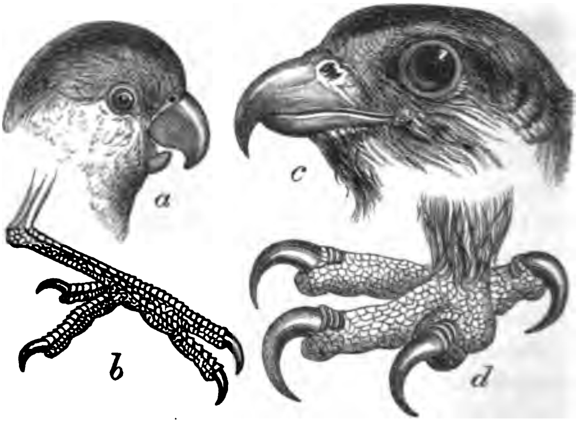


Fig 126. SCANSORES AND RAPTORES.

a, Head of Iris Parrot (*Iris coriphilus*); *b*, foot of Ivory-billed Woodpecker (*Picus principalis*); *c*, head of Peregrine Falcon (*Falco peregrinus*); *d*, foot of Golden Eagle (*Aquila chrysaëtos*).

The *Cuculidæ* or Cuckoos; *Picidæ* or Woodpeckers; *Psittacidæ* or Parrots; and Toucans (*Rhamphastidæ*), typically exemplify the order.

Order 6. *Insessores* (*Passeres*), (Perchers).—This group is the most extensive of the class, including, as it does, the great majority of our common and familiar Birds.

The *Insessorial* or *Passerine* Birds are distinguished chiefly by their negative characteristics, or, in other words, by the want of the special and diagnostic features which characterise the other orders of the class. In general they are of small size; the legs are usually slender, and of the four toes with which they are provided, three are situated anteriorly (Fig. 127, *b*), the fourth being ordinarily directed backwards, although

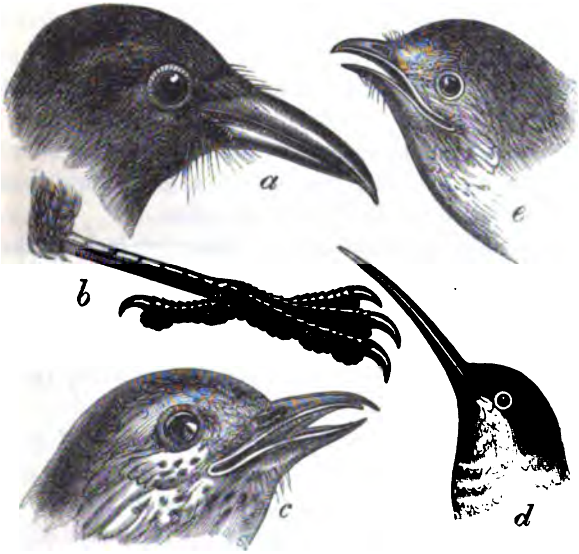


Fig. 127. INSESSORES.

a, *Conirostres*; head of Carrion Crow (*Corvus corone*); *b*, foot of Carrion Crow; *c*, *Dentirostres*; head of Singing Thrush (*Turdus musicus*): *d*, *Tenuirostres*; head of Topaz Humming-bird (*Trochilus pella*); *e*, *Fissirostres*; head of Swallow (*Hirundo rustica*).

in several instances, and most notably in the case of the Swifts, the whole of the toes are turned forwards. The structure of the foot, the disposition of the toes, and the muscular arrangements of the leg, are eminently adapted for perching; and also serve as important aids in the construction of the nest, the many varieties of which form a characteristic feature of the group. The wings are in general large, and the power of flight is possessed in great perfection throughout the group.

The variations in the conformation of the beak afford means of classifying this extensive group, which is accordingly divided into four sub-orders.

Sub-order (*a*) *Dentirostres.*—This group includes the Shrikes (*Laniidæ*); Thrushes and Blackbirds (*Merulidæ*); Flycatchers (*Muscicapidæ*); and Warblers (*Sylviadæ*); in all of which forms the upper mandible is more or less hooked, and toothed or serrated at its tip (Fig. 127, *c*).

Sub-order (*b*) *Conirostres.*—The members of this group are distinguished by the conical shape of the bill (Fig. 127, *a*), and by the absence of notches in the upper mandible. Crows, Magpies, and Jays (*Corvidæ*); Starlings (*Sturnidæ*); Finches, Linnets, and Larks (*Fringillidæ*); represent this sub-order.

Sub-order (*c*) *Tenuirostres.*—The Creepers (*Certhidæ*); Humming Birds (*Trochilidæ*), and Hoopoes (*Upupidæ*), representing this group, are distinguished by the slender and pointed conformation of the beak (Fig. 127, *d*), which in some cases is straight, or in others curved to a greater or less degree. The majority live on insects, but certain species subsist on the juices of flowers, the tongue being in the latter case specially adapted, as previously noticed, for the function of imbibing the delicate fluids of plants. These latter forms are represented by the many species of Humming Birds, which are noted alike for the delicacy of their form, the brilliance of their plumage, and their peculiar geographical distribution, which latter feature has been thus described by Professor Allman:—"While all these beautiful little creatures are absolutely confined to America, they have a singularly wide distribution in latitude. The centre of their area is Equatorial America, where a tropical sun is flashed back from their plumage of emerald, and sapphire, and ruby; and yet specimens have been brought from Sitka, on the Pacific coast of Russian America; while south of the equator they extend their range as far as the desolate shores of Tierra del Fuego."

Sub-order (*d*). *Fissirostres.*—The beak in this group is more or less deeply cleft, by the line of separation of the mandibles being continued far backwards on the head (Fig. 127, *e*). The mouth or "gape," being thus rendered wide and capacious, aids in the capture of insects, which these Birds pursue on the wing, and on which they principally subsist. The margins of the gape are provided with bristle-like filaments, which also assist in the capture of the insect-prey.

Swallows (*Hirundinidæ*); Swifts (*Cypselidæ*); Goat-suckers (*Caprimulgidæ*), and Kingfishers (*Alcedinidæ*), typically represent this latter group.

Order 7. *Raptores* (Birds of Prey).—The *Raptorial* Birds, represented by the Eagles, Falcons, and Hawks (*Accipitrinæ*); and by the Owls (*Strigidæ*), are distinguished by their predaceous habits, which, together with the concomitant structural features, render the group one of the best defined orders of the class. The upper mandible projects beyond the lower one (Fig. 126, *c*), and being hooked at its extremity, and sometimes serrated or toothed along its edges, constitutes the chief agent in the tearing and division of the prey. The legs are generally short, but are extremely muscular and strongly set. The toes are four in number, three being situated anteriorly, and one posteriorly (Fig. 126, *d*); whilst each toe is armed with a sharp hooked claw, or "talon," as it is technically called. The wings are large, and the powers of flight are accordingly very great. The young correspond to the *Heterophagous* section of the class, being born in a comparatively immature state, and being entirely dependent for a longer or shorter period on the care of the parent-bird.

The *Raptorial* Birds fall into two natural groups, characterised by the period of the day at which they respectively fly abroad. Thus the Eagles, Hawks, Kites, Falcons, and Vultures (*Vulturidæ*), exemplify the *Diurnal Raptores;* whilst the Owls represent the *Nocturnal* Birds of Prey.

Order 8. *Saururæ.*—This order includes but a single extinct form (Fig. 128), to which the name of *Archæopteryx* or "Ancient-wing," has been given. Fossil remains of this form have been found in the Oolitic

Limestone of Germany, in common with the remains of the *Ichthyosaurus* and *Pterodactyl.* Some doubt exists as to the true nature of this singular fossil, which, whilst it shows undoubted marks of identity with the structure of the Bird, bears close relations to the Reptilian type of structure also.

The wing was provided with two free claws (Fig. 128, *f*), and the tail, which was "longer than the body," was composed of distinct vertebræ (*a*), but destitute of a "pygostyle" or "ploughshare-bone." These features, together with other anomalous structural points, tend to render the exact position of the *Archæopteryx* a matter of theory and speculation. An idea of the appearance of this curious form will be best obtained from the accompanying illustration (Fig. 128), depicting the *Archæopteryx* in its restored state.

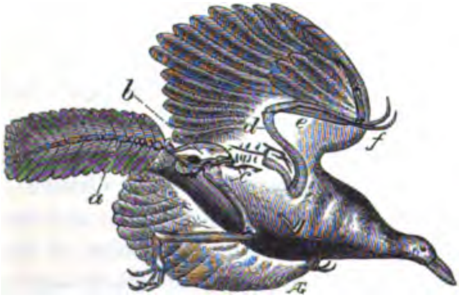


Fig. 128. SAURURÆ.

Restoration and parts of skeleton of *Archæopteryx macrura* (Oolitic) (Owen); *a*, Vertebræ of tail; *b*, pelvis; *c*, femur; *d*, humerus; *e*, fore-arm; *f*, terminal free digits of wing.

CHAPTER XXVII.

VERTEBRATA.

PROVINCE C.—MAMMALIA.

CLASS V.—MAMMALIA.

General Characters and Classification of Mammalia.

THE class *Mammalia* includes those animals familiarly known as Quadrupeds, and which may be shortly defined as "warm-blooded, air-breathing, viviparous Vertebrates." In this, the highest division of the animal series, the perfection of organs and functions is accordingly attained; the boundaries of the class being defined by several well-marked and special characteristics. The diagnostic features of the group consist, firstly, in the nature of the body-covering, which consists of hairs, the development of these appendages varying greatly throughout the group. A second and highly distinctive feature of the *Mammalia* is found in the possession by these animals of "mammary glands," or special organs devoted to the secretion of milk, by means of which the young animal is nourished for a longer or shorter period. The structure and relations of the lungs form a third characteristic of the group, these organs existing in the present instance as closed sacs, suspended in a shut cavity,—the "thorax" or chest, which is now separated from the abdomen by a muscular partition, known as the "diaphragm" or "midriff" (Fig. 92, *j*). The blood of the *Mammalia* is warm; and the blood-corpuscles present a fourth distinctive feature of the class, in that they are "non-nucleated" (Fig. 94, A), and in the great majority of instances are more or less circular in form. The skull articulates with the spine by means of two "occipital condyles;" and the lower jaw, the halves of which consist each of a single piece only, articulates directly, and of itself, with the skull. These characters, contrasting forcibly with the disposition of the homologous structures in the *Sauropsida*, form a fifth characteristic of the class.

The disposition of the circulatory organs is essentially similar to that found in Birds; the heart in the *Mammalia* consisting of four chambers, and the venous being distinct from the arterial circulation. The nervous system exhibits certain features of structural perfection, to be afterwards more particularly noticed; and when we lastly observe that the reproduction is essentially and typically of the "viviparous" description, we shall have completed the ordinary definition of this important group.

The general morphology and physiology of the *Mammalia* having been already described in the introduction to the *Vertebrata*, it will be unnecessary in the present instance to enlarge upon the more general points of structure: the few remaining and more special features in the various systems and organs may therefore be briefly described by way of introduction to the classification of the division.

The skin of mammals, as already noticed, is more or less abundantly covered with epidermic appendages known as "hairs." The development of these structures varies greatly throughout the class, the *Cetacea* or Whales presenting the most noted exception to the rule, in that the bodies of these creatures are in many cases totally destitute of hairs. Modifications of the ordinary epidermal covering of *Mammals* are found in the scales and bony plates of certain *Edentata*, such as the Armadillos; and in the bristles and spines of the Hedgehog and Porcupine; the homology of these modified structures with hairs, as productions of the epidermis, being readily traceable.

The skeleton of the *Mammalia* (Fig. 91), whilst exhibiting a very decided affinity of type throughout the group, presents, in certain instances, marked deviations from the typical plan of structure. Thus the *Cetacea* or Whales, as fitted for an aquatic existence, diverge most widely in the disposition of their skeleton from the ordinary type; and modifications in parts and regions are accordingly to be observed in this instance. The vertebral column is, however, generally divisible into the regions previously described. The cervical segments (Fig. 91, *b*) present the greatest constancy in number, these vertebræ rarely exceeding seven. The dorsal region (Fig. 91, *d*) generally consists of from ten to twenty or more vertebræ, this region thus exhibiting great variations in length. The spinous or neural processes of the dorsal vertebræ are usually large and well developed, to afford attachment to the ligaments which support the head, the chief of these being known as the "ligamentum nuchæ." The lumbar vertebræ (*e*) rarely exceed seven in number, and the sacral region is composed of from two to five segments, which in most cases are ossified together, to form, in the adult animal, a single bone—the sacrum (*f*). In the *Cetacea* the sacrum is wanting. The caudal vertebræ (*g*), constituting the tail, are subject to great variation in number. In Man these vertebræ are abortive, and are represented by four small segments forming the "coccyx;" whilst in ordinary cases they are exceedingly numerous, and vary in number from fifteen to forty segments.

The ribs (*h*), forming the sides of the thorax or chest, correspond in number with the dorsal vertebræ, and are usually divided into the "true" and "false" ribs. The former are joined to the sternum or breastbone by cartilages (*i*)—the homologues of the sternal ribs of Birds and Reptiles—and to which the term "costal cartilages" is applied; the "false ribs," on the contrary, are short and stunted, and are not joined to the sternum. The breastbone is generally flattened from before backwards, and is but rarely compressed from side to side. The keel or ridge, forming so prominent a feature in the sternum of Birds, is observable in a greatly modified form, in a few instances (Bats, Moles, etc.) only. The bones of the shoulder-girdle vary in number and development. A scapula or shoulder-blade (Fig. 91, *c*), is invariably present, but the clavicles or collar-bones may be rudimentary, as in the *Carnivora* (Fig. 91, *k*), or altogether wanting, as exemplified by the *Cetacea, Ungulata*, etc. The coracoid bone—so remarkable an element in the pectoral arch of the Bird (Fig. 119, *a*)—is, in nearly every instance, ossified to, and forms a mere process of, the scapula; whilst the clavicles or "collar-bones" are never united together to form a distinct "furculum," or "merry-thought," as in Birds.

The anterior limbs are invariably present in *Mammalia*, although the skeletal elements of these members vary greatly in development. The humerus (Fig. 91, *l*) is generally to be recognised, and the radius and ulna (*m*, *n*), whilst usually existing as distinct bones, are sometimes ossified together, to form a single bone. The carpus (*o*) is formed by an inconstant number of small bones, arranged in a double row; and the metacarpus (*p*) is generally composed of five bones, although this arrangement, in certain hoofed quadrupeds, is widely departed from. The number of digits is also usually five, but the disposition of these bones varies greatly throughout the group. The thumb digit may be absent or rudimentary; this latter finger being composed of two phalanges, whilst the other digits usually possess three.

The pelvic arch is subject to great modifications, and, as in the *Cetacea*, may be of very rudimentary description. The "innominate bones" (Fig. 91, *r*), forming the sides of the pelvis, are in the fully-grown animal usually united to the vertebral column, and are also joined together in the middle line by ossification, or by firm cartilaginous attachments; but in some cases the halves of the pelvic arch are merely united by ligamentous tissues. The hind limbs are sometimes wholly wanting, as in the *Cetacea;* but when present these members generally exhibit the typical parts already described. The tibia (*u*) and fibula (*v*) may be united together in an incomplete manner, the latter bone being present in several instances in a rudimentary condition. The metatarsal bones (*x*), like their prototypes of the pectoral members, vary in number, development, and disposition. The foot is composed usually of five digits, the terminal phalanges of both anterior and posterior members being generally provided with claws, hoofs, or nails.

The skull (*a*) articulates with the vertebral column by means of *two* occipital "condyles," and exhibits a material divergence from the *Sauropsidan* type, in the simple structure of the "rami," or halves of the lower jaw; and, as previously observed, in the absence of an "os quadratum"—the lower jaw articulating directly with the cranium. The facial bones are firmly united together by anchylosis, or bony union, and the "cranial sutures," or junctions of the cranial bones, generally remain visible throughout life, and do not, as in Birds, become early and permanently obliterated.

The digestive system, presenting a uniformity of type throughout the class, has been already noticed in detail. The teeth, however, demand special attention, as, on their structure and disposition in the various orders, the ordinary classification of the *Mammalia* has been principally based.

Two sets of teeth are found throughout life in the majority of Mammals. The first, termed the "deciduous," "milk," or "temporary" set, is developed at an early period of the animal's existence, and, as its name implies, gives place at a sooner or later period to the second and "permanent" set. Those Mammals in which the perfection of dental development is thus reached, have accordingly been termed "Diphyodont" *Mammalia;* whilst those forms which possess only one set of teeth are, in contradistinction, named "Monophyodont" *Mammalia.* The teeth are lodged in distinct sockets, or "alveoli," and are confined in their disposition to the jaw-bones; these latter features forming a strong contrast to the arrangements observed in the majority of the lower Vertebrata. Regarding the homology of the teeth, it may be well to notice that comparative anatomists are by no means well agreed; one party maintaining the identity of the teeth with other and "dermal" secretions, whilst the other side seek to show the homology of the teeth with the true osseous material. In other words, the advocates of the former theory regard the teeth as belonging to the exoskeleton, whilst the latter consider that these organs are more properly included as parts of the endoskeleton.

The intimate structure of the teeth is essentially similar throughout the class; the various elements exhibiting slight variations in disposition, in accordance with the particular food of the included forms. Thus, as exhibited in the diagrammatic section of an incisor tooth from the human subject (Fig. 129, B),

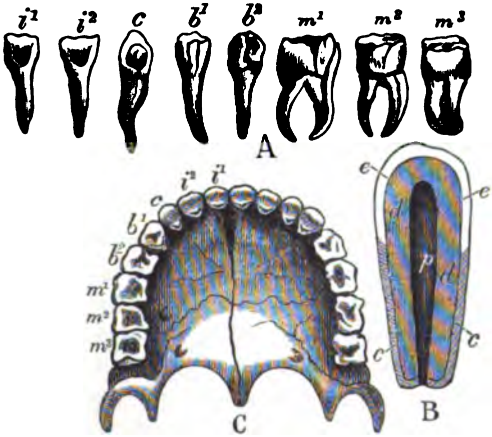


Fig. 129. Teeth of Mammalia.

A, The teeth of Man, removed from the half-jaw to show their form; i^1 i^2, incisors; *c*, canine tooth; b_1 b_2, bicuspid or præmolar teeth; m^1 m^2 m^3, molars. B, Section of incisor tooth of Man, to show its structure; *c c*, cement; *d d*, dentine; *e e*, enamel; *p*, pulp-cavity. C, Teeth of human subject, as seen *in situ* in the upper jaw. References as in upper figure.

the body of the tooth (*d*) is composed of a substance to which the name of "dentine" or "ivory" is given; the fang or root is invested by a layer of "cementum" or "cement" (*c c*); whilst the "crown" is covered by a substance of great hardness termed "enamel" (*e e*), and which serves on this account to protect the "crown," and prevent the too rapid attrition or wear of the tooth. Internally, the pulp-cavity (*p*) of the tooth is seen. This cavity contains a highly-vascular tissue, richly supplied with nerves, and termed the "dental pulp;" the development, growth, and nourishment of the dental tissues being carried on by means of this structure.

Regarding the form and functions of the teeth, four varieties are to be distinguished. The first kind comprehends the "incisor" or "cutting" teeth (Fig. 129, A, C, *i*). These are placed in the front of the jaw (Fig. 129, C, i^1 i^2), and are characterised by their sharp chisel-like edges. Functionally, the incisors are, as implied by their name, the "cutters" or "dividers" of the food, and in the *Rodentia*, exemplified by the Hare, Beaver, etc., the incisor teeth are greatly developed, and form the organs with which the "gnawing" operations of these creatures are carried on. The second series of teeth are known as the "canine" or "eye" teeth (Fig. 129, A, C, *c*). These teeth are situated next the incisors in each side of the jaw, and derive their name from the fact of their especial development in the *Carnivora*, exemplified by the Lion, Dog, etc. The "bicuspid," "præmolar," or "false molar" teeth (b^1 b^2), succeed the "canines," and are distinguished by their relatively broader crowns, each "bicuspid" tooth bearing on its crown two points or cusps, from the possession of which the name of these teeth is derived. The fangs of the "bicuspid" teeth further exhibit a tendency to become bifurcated, or divided in two. The fourth and last variety of teeth is known as the "molars" or "grinders" (Fig. 129, A, C, m^1 m^2 m^3):

these teeth possessing two or even three fangs, and being distinguished by their broad flattened crowns, which adapt them for the particular function of crushing and grinding the food. The molars of the upper jaw in the human subject possess four cusps, whilst those of the lower jaw are provided with five points. The "deciduous" or milk set of teeth is composed of three kinds of teeth only; incisors, canines, and præmolars; the true molars being thus unrepresented in the milk set, and making their appearance for the first time in the permanent set.

These various and typical varieties of teeth, although fully represented in the higher forms, are not necessarily present in their entirety throughout the whole class; on the contrary, we find many and very great modifications in the number and disposition of the teeth as we descend the scale; the arrangements of necessity varying with the life and habits of the animal. The various modifications of dental structure and arrangement will therefore be more appropriately treated of under the various subdivisions of those groups in which the most typical variations occur; but it may, however, be appropriate, in the present instance, to notice the means adopted by naturalists to express the dental arrangement of a particular animal or group. For the sake of brevity and convenience, the zoologist employs a particular arrangement of signs and numbers, corresponding to the kinds and number of the teeth, and to this arrangement the name of "dental formula" has been given. The following formula, representing the dentition of the adult human subject, in whom thirty-two teeth are found, will serve to illustrate the system under consideration:—

$$\mathrm{I}\ \frac{2-2}{2-2}\ \mathrm{C}\ \frac{1-1}{1-1}\ \mathrm{B\ or\ PM}\ \frac{2-2}{2-2}\ \mathrm{M}\ \frac{3-3}{3-3} = 32$$

In the above formula, therefore, the letter I indicates the "incisor" teeth, which, from their central position in the jaw (Fig. 129, C, i^1 i^2) are first examined. The figures above the horizontal line represent the incisor teeth in the upper jaw, and these upper figures are further subdivided to represent the incisor teeth in each half of the upper jaw. In a similar manner we express the number of incisor teeth in the lower jaw by placing figures below the line, and, as before, indicate the number of teeth in each half or side of the jaw, by dividing the lower figures. The other teeth are similarly dealt with, and the whole formula accordingly reads thus:—Incisor teeth, two in each half of the upper jaw, and two in each half of the lower jaw—four in each jaw, or eight in all: Canine teeth, one in each half of upper, and one in each half of lower jaw, or four in all: Præmolars or Bicuspids, two in each half of upper, and two in each half of lower jaw, or eight in all; and Molars, three in each half of each jaw, or twelve in all; making a total of thirty-two teeth—the number of teeth in the permanent set of man. Or, if we wished to express the dentition of the *Feline Carnivora*, comprising the lions, tigers, cats, etc., the following formula would, in a similar manner, be constructed:—

$$\mathrm{I}\ \frac{3-3}{3-3}\ \mathrm{C}\ \frac{1-1}{1-1}\ \mathrm{PM}\ \frac{3-3}{2-2}\ \mathrm{M}\ \frac{1-1}{1-1} = 30.$$

In the latter example we have three incisors in each half of each jaw; the canines exist as in man; the præmolars number three in each half of the upper jaw, and two in each half of the lower jaw; whilst the molars exist to the number of one in each side of each jaw; and the total number of teeth in the *Felidæ* is therefore thirty. Thus, from much experience, the practised naturalist is enabled to tell the history of any given animal from a mere inspection of its "dental formula."

The intestine in the lower members of the class opens into a "cloaca," or chamber common to the efferent ducts of the alimentary and genito-urinary systems.

The heart (Fig. 92, *w*) is enclosed in a serous sac or "pericardium," and exhibits the highest perfection of structure. The circulation in Mammals (Fig. 95) has already been described. The lungs (Fig. 92, *x*) are now contained in the thorax or chest, a cavity enclosed by the ribs, spinal column, and breastbone, and partitioned off from the abdomen by a "diaphragm" (Fig. 92, *j*), which is to be regarded as the principal agent in effecting the expansion and contraction of the thorax in the movements of respiration. The lungs are thus closed sacs, and present, as previously remarked, a striking contrast to the disposition of the respiratory system in Birds.

The nervous system in the lower *Mammalia* bears marks of close affinity to the conformation of the nervous centres in the preceding class; but in the higher members of the group the "cerebrum," or true brain (Fig 92, *b*), shows an increased development, and assumes a relatively larger size when compared with the "cerebellum" (*c*), or lesser brain. A distinctive feature between the higher and lower *Mammals*, and between the *Mammalia* and the preceding classes, has been founded on the fact that the "corpus callosum," or great commissure of the brain—a band of nervous matter connecting the halves or "hemispheres" of the true brain—is distinctly developed in the higher members of the group, but is indefinite, rudimentary, or altogether absent in the lower *Mammalia*.

In their reproduction *Mammals* are strictly "viviparous," the young being thus born alive, and in a comparatively helpless condition. The "amnion" and "allantois" are developed to a very perfect extent; the latter structure giving origin, in the higher forms, to the embryonic appendage known as the "placenta," or organ by means of which a vascular connection is maintained between the embryo and the parent before birth, or during the period of intra-uterine life.

Classification.—The *Mammalia* have been made the subject of numerous systems of classification; various and widely different features in the organisation of the group having been made the bases of these arrangements. Thus, in the system of Professor Owen, the structure and relative perfection attained by the brain has formed the ground on which the class has been divided into four sub-classes. De Blainville's system, relying on the nature, and variations in disposition, of the reproductive organs, subdivides the *Mammalia* into three sub-classes; whilst, according to the older mode of classification, the presence or absence of a "placenta" has been used to subdivide the class into two primary groups or sections. The first system, that of Owen, from the peculiarly difficult nature of obtaining exact data of observation, has not been generally accepted; that of De Blainville, whilst thoroughly scientific, is of too technical a character for our present requirements; and the third system, offering simple and easily understood features, may be adopted in the present instance.

The various orders of the class, grouped under the primary sections formed by these various systems, have, with few exceptions, remained intact; the difference between these systems of classification consisting chiefly in the variable nature of the primary sections or subclasses of each author. The orders of *Mammalia*, it may also be well to mention, have been subjected to considerable change in nomenclature and limits; more careful examination of the included forms resulting either in the formation of new orders, or in the extension and enlargement of the old. For the sake of simplicity, consistent with accuracy, the older classification has in greater part been retained.

The *Mammalia* are thus divided by the presence or absence of a "placenta," into the (A) *Implacental* or *Aplacental Mammals*, and the (B) *Placental Mammals;* these terms being synonymous with the *Lower* and *Higher Mammalia*. In the *Implacentalia*, a "placenta" is wanting, and the young "fœtus" or "embryo" is simply retained in the maternal uterus, without possessing any vascular connection with the mother. The young in this section are born in a comparatively helpless condition, and are entirely dependent upon the mother for support. The *Placentalia* include those Mammals in which a "placenta" is present, the "fœtus" thus possessing a vascular connection with the mother, and being nourished through this medium by the blood of the parent. The young in this latter section are dependent for support to a much less extent after birth upon the mother, and are born in a comparatively advanced state of perfection.

The *Implacentalia* include the two following orders:—

SUB-CLASS A. IMPLACENTALIA.

Order 1. *Monotremata.* Ex. Ornithorhynchus.
Order 2. *Marsupialia.* Ex. Kangaroo, etc.

Under the *Placentalia* the following orders are included:—

SUB-CLASS B. PLACENTALIA.

Order 3. *Edentata.* Ex. Sloth, etc.
Order 4. *Sirenia.* Ex. Dugong, etc.
Order 5. *Cetacea.* Ex. Whale, etc.
Order 6. *Ungulata.* Ex. Horse, Sheep, Elephant, etc.
Order 7. *Carnivora.* Ex. Lion, Dog, etc.
Order 8. *Rodentia.* Ex. Rat, Beaver, etc.
Order 9. *Insectivora.* Ex. Mole, etc.
Order 10. *Cheiroptera.* Ex. Bat.
Order 11. *Quadrumana.* Ex. Monkey, etc.
Order 12. *Bimana.* Ex. Man.

CHAPTER XXVIII.

VERTEBRATA.

PROVINCE C.—MAMMALIA—(*Continued*).

Classification of Mammalia.

SUB-CLASS A. IMPLACENTALIA.—In this section of the class there exists no "placenta," or vascular connection between the parent and offspring before birth. The "corpus callosum," or great commissure of the brain, forming a connecting band of nervous matter between the hemispheres of the cerebrum, is imperfectly developed in the sub-class before us; indeed, its existence in any form, and however rudimentary, has been denied by some authorities. The only other feature which may be alluded to in describing the general characteristics of these forms, is their geographical distribution, which, as will be afterwards noticed, is of a very limited description.

The sub-class contains two orders—the first of which, that of the *Monotremata*, includes two genera only; the *Marsupialia*, forming the second order, being a more extensive group, and being represented by the Kangaroos, Opossums, and their allies.

Order 1. MONOTREMATA.—This order includes but two genera, both of which are confined to Australia. In their structural features, the *Monotremata* show a very decided relationship to the preceding class of Birds. Thus, the bones of the skull, as in Birds, are united together at an early period of the animal's existence, the sutures being obliterated; whilst in the general conformation of the cranium, in the broad flattened bill into which, in one form, the facial bones are prolonged, and in the peculiar arrangement of the bones of the pectoral arch, the special characteristics of Bird-structure are clearly discernible. As in Birds, also, a "cloaca," or chamber, common to the terminal ducts of the alimentary, urinary, and generative systems, exists, and from this latter circumstance the technical name of the order has been derived. The fact of the common terminations of these various systems has also been regarded by De Blainville, in his classification of the Mammalia, as of sufficient importance to justify the separation of the *Monotremata* to form a distinct sub-class, under the name of *Ornithodelphia;* a term obtained from the obvious similarity of this arrangement in the *Monotremata* to that seen in Reptiles, and more especially in Birds. The *Ornithorhynchus*, "Duck-billed Platypus," or "Water-Mole of Australia" (Fig. 130), is the typical representative of this curious group. Externally, this animal presents the following characters:—in shape it somewhat resembles the Common Otter of our own rivers; its body is coated with a soft, short, brown fur; the tail is broad and flattened, and serves as a powerful agent in swimming; the legs are shortened, and the feet are each terminated by five toes, furnished with claws, and united, as in aquatic Birds, by a web or membrane. The head is small, the jaws terminating in the broad expanded bill, previously alluded to, and from which the term "duck-billed" has been derived.

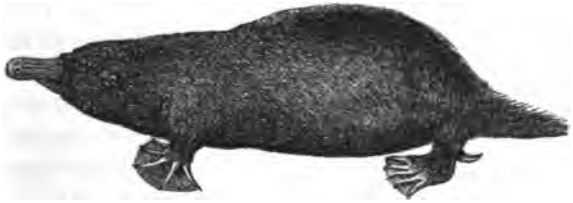


Fig. 130. MONOTREMATA. *Ornithorhynchus paradoxus.*
The "Duck-billed Platypus," or "Water-Mole of Australia."

The chief points of interest to be noticed in the osteology of the group, and those in which the skeleton may be said to depart from the ordinary Mammalian type of structure, consist in the conformation of the skull, and in the arrangement of the pectoral arch. The cranium proper is of small size, as compared with the facial bones, and the jaws are either covered, as in *Ornithorhynchus*, with horny plates, or are destitute of any covering whatever. The *Echidna* exemplifies the latter case; no teeth being thus developed in either genus. The bones of the shoulder-girdle approach most nearly to the *Sauropsidan* arrangement, in that the "coracoid bones" are largely developed, and articulate directly, as in Birds, with the sternum; whilst the two clavicles unite as in the preceding class, to form a T-shaped bone—the "furculum," which rests upon the superior aspect of the sternum. The pelvis bears some resemblance to that of *Reptilia*, but exhibits characteristics allied to the structure of Birds also. The most remarkable feature, however, in the pelvic osteology is seen in the peculiar and modified structures known as "marsupial bones (Fig. 131, *a a*). These bones, which may be regarded as characteristic of the *Implacentalia*, and which are functionally useless in the present instance, are found in greater perfection in the succeeding order of the *Marsupialia* or "Pouched" Mammals. They consist of two elongated bones attached to the front of the pelvis; their office being to support a "marsupium" or "pouch," which is used in the *Marsupials* to lodge and protect the young in the earlier stages of their growth. The homology of these peculiar bones has formed subject-matter for considerable discussion; but they are now generally regarded as ossifications of the inner tendon of the "external oblique" muscle of the abdomen; and as such are to be ranked with the knee-cap or "patella" (Fig. 91, *t*), and the other sesamoid bones developed in the muscular or tendinous structures of the great toe and thumb.

The *Ornithorhynchus* (Fig. 130), of which only one species (*paradoxus*) has as yet been discovered, appears to be mainly insectivorous in its habits, feeding upon insects, worms, etc., which it obtains in the rivers, the banks of which it frequents, and in which it swims with great facility by means of the webbed feet. The nest is situated at some distance from the river-bank, with which it communicates by an underground burrow, often of considerable length. The male *Ornithorhynchus* possesses a "spur" (Fig. 130), attached to the tarsi of the hind-legs, and which has been accordingly termed the "crural spur." This structure communicates internally with a gland, the efferent duct of which opens at the apex of the "spur." The function of this peculiar appendage, which would seem apparently to be that of an offensive apparatus, has not been accurately determined; these creatures, even when irritated, making no use of the "spur" as a means of defence.

The *Echidna* or Porcupine Ant-eater, forming the remaining genus included in this order, and of which two species (*E. setosa* and *E. hystrix*) are known, differs from the *Ornithorhynchus* in being covered by bristly spines. The jaws are prolonged to form a snout, at the extremity of which the nostrils are situated. The feet are provided with powerful claws; the toes, however, which exist to the number of five on each foot, being free and ununited by a web or membrane. The mouth is destitute of teeth, but is provided with an elongated protrusible tongue, by means of which the animal seizes the ants and insects upon which it subsists.

The geographical distribution of the *Monotremata* is exceedingly limited, these forms being exclusively confined to Australia and Tasmania; whilst their geological relations are undetermined; no traces of these forms having as yet been found in a fossil condition.

Order 2. MARSUPIALIA.—This order, whilst presenting many points of similarity to the preceding group, is, nevertheless, to be considered of more advanced organisation. The animals included within its limits are distinguished, as implied by the technical name of the group, by the possession, in the case of the females, of a "marsupium," or "pouch," formed by a fold of the abdominal integument, and supported by the "marsupial bones" (Fig. 131, *a a*), previously alluded to. The

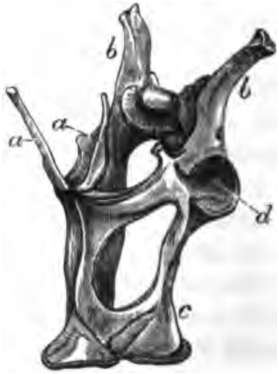


Fig. 131. OSTEOLOGY OF MARSUPIALIA.

Pelvis of Kangaroo (*Macropus*); *a a*, marsupial bones; *b b*, ilia; *c*, ischium; *d*, acetabulum, or socket for head of thigh-bone.

Kangaroos of Australia (Fig. 132, *a*), and Opossums of America (Fig. 132, *b*), may be cited as familiar examples of the order, which is distinguished from the preceding group by certain well-marked characteristics. These consist, firstly, in the conformation of the skull, and in the nature of the union between the cranial bones; these bones being united as in other Mammalia, by sutures, which are generally persistent throughout life. The jaws are provided in every instance with teeth, these organs exhibiting the usual varieties in form and function. The disposition of the bones of the shoulder-girdle forms a second diagnostic feature of the *Marsupialia,* as compared with the *Monotremata.* The pectoral arch in the present instance is accordingly found to be modelled after the ordinary Mammalian type—the coracoid bones being greatly modified in their development, not articulating in any way with the sternum, and existing as mere processes of the scapula, or shoulder-blade. The invariable presence of "marsupial" bones (Fig. 131, *a a*), and almost universal presence of a "marsupium," or pouch, in which the young are carried and protected for a considerable period after birth, forms a third and characteristic feature of the group. As we have seen, the mere presence of marsupial bones does not constitute the special character of this feature, since these structures exist in the *Monotremata* also; but the existence of a "marsupial pouch," supported on these bones, forms a feature highly characteristic of the present forms. These bones are present alike in the males and females, but it is only in the female animal that the "pouch" is found. In some Opossums, and in the genus *Dasyurus,* the marsupial pouch is wanting in the females also; the invariable presence in such forms, however, of the "marsupial bones," maintaining the value of the character thus constituted.

In this abdominal sac the mammary glands are contained, the teats being of large size, and projecting into the cavity of the pouch. The young are, after birth, placed in the pouch, and are thus well situated for obtaining, in the most convenient manner, the supply of nutrient matter so necessary to their feeble and immature condition. A very characteristic and curious feature in the nourishment of the *Marsupialian* young consists in the provision made for the due supply of the mammary secretion, by means of a special muscular development, which compresses the mammary glands so as to inject the milk into the mouths of the attached and helpless offspring. The danger to the young animals so attached, of suffocation, is averted by a special provision, consisting in the prolongation upwards of the larynx to the soft palate, by which means the air-passages are completely separated from the œsophagus, and respiration, as in the Whales, is thus carried on independently of the act of nutrition.

The involuntary nature of the nutritive act, as thus performed, constitutes an admirable provision for the nourishment of the young, under the circumstances in which they are produced; this process continuing until such time as the young animals are better developed, and can enter or leave the pouch at will.

The *Marsupialia*, forming the sub-class *Didelphia* of De Blainville's system of classification, present certain features in the disposition of their reproductive system, of special interest, as serving to materially distinguish them from the preceding order. This fourth distinctive feature consists in the double nature of the generative organs, the terminal ducts of which are distinct, and open, in common with the urinary ducts, into a "uro-genital canal;" which, however, is quite distinct from the rectum, this latter duct opening by a separate anal orifice.

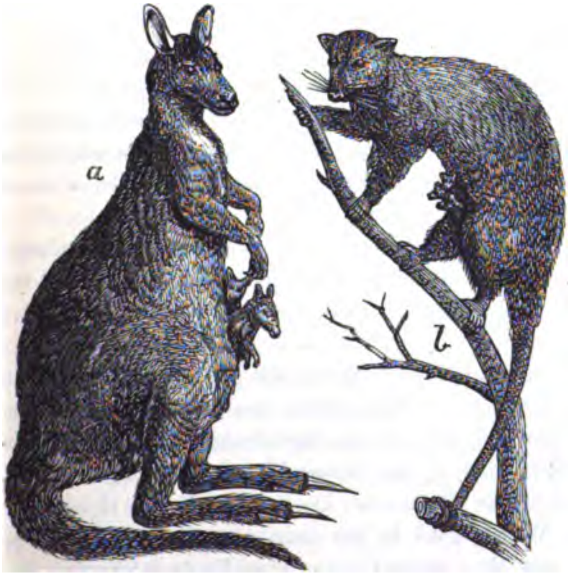


Fig. 132. MARSUPIALIA.
a, The Woolly Kangaroo (*Macropus laniger*), with young protruding from the "marsupium." *b*, Opossum (*Didelphys ornata*).

The "corpus callosum" of the brain evinces a higher degree of specialisation than that observed in the *Monotremata*, whilst the convolutions of the cerebral surface are better marked than in the latter group. The brain is also of relatively larger size, and is better developed in the *Frugivorous* than in the *Carnivorous* Marsupials. The skin in these forms is in every case covered with fur or hair; the spiny developments seen in the Monotrematous *Echidna* being totally wanting in the present instance.

The order has been divided into various sections, distinguished chiefly by the nature of the food; and, roughly speaking, the *Marsupialia* may accordingly be classified in two such groups, known respectively as the *Phytophagous* or Plant-eating, and the *Carnivorous*, or Flesh-eating forms.

Of the former group the *Phascolomydæ* or Wombats; the *Macropodidæ* or Kangaroos (Fig. 132, *a*), and the *Phalangistidæ* or Phalangers, are the representative families.

The *Carnivorous* Marsupials are represented by the *Peramelidæ* or Bandicoots; the *Didelphidæ* or Opossums (Fig. 132, *b*); the *Myrmecobiidæ* or Banded Ant-eaters, and by the *Dasyuridæ* or Dasyures, otherwise known as "Tasmanian Devils" or "Native Hyænas."

With regard to the distributional aspects of these forms, they present many exceedingly interesting features for consideration in the twofold aspect in which the subject may be viewed. Their geographical distribution presents a striking contrast to their distribution in time, in that these forms, which are confined to a limited area in the present world, enjoyed a distribution in past ages as extensive as their present distribution is now limited and confined. With the exception of the Opossums, the *Implacental* Mammals are confined exclusively to the Australian Continent; the *Didelphidæ*, however, being exclusively found in America. The indigenous *Mammalia* of Australia, therefore, so far at least as the present state of our knowledge enables us to determine, belong wholly to the *Implacental* division of the class; the causes of this present limitation in distribution being probably founded on physical conditions, which the imperfection of the geological record renders us unable readily or satisfactorily to trace.

The earliest appearance of the *Marsupialia* as fossil organisms, probably occurs in the upper Trias rocks; these fossils consisting of the lower jaw and teeth of a small insectivorous Mammal known as *Microlestes*, and which appears to be allied to the Banded Ant-eater (*Myrmecobius*) of the present day. As no traces of fossil *Monotremata* have as yet been found, the *Microlestes* fossil is thus doubly interesting, as introducing us to the earliest appearance of *Mammalian* life upon our globe.

CHAPTER XXIX.

PROVINCE C.—MAMMALIA.

Classification of Mammalia—(*Continued*).

SUB-CLASS B. PLACENTALIA. — Order 3. EDENTATA (BRUTA).—The term "toothless," applied to this order, the first and lowest of the *Placental* Mammalia, is, it must be confessed, somewhat of a misnomer, since teeth are present in nearly every case, although the dental structure is somewhat modified from the ordinary *Mammalian* type. Incisor teeth are present in one instance only, the canines in most cases are wholly wanting, whilst in two instances only no teeth of any description are found. Further, the teeth are of less complicated structure than in the other groups; these organs in the present group being described as each composed of "a cylinder of bone, enclosed within a simple case of enamel, but without any of the convolutions of these substances which characterise the structure of these organs in the *Ruminantia* and other graminivorous animals." In the *Edentata* the teeth are unprovided with distinct roots, and one set only is, in the majority of instances, developed throughout the life of these animals.

The order divides itself naturally into two sections, distinguished by the respective nature of the food in each. The first section, that of the *Phytophaga*, is characterised by the vegetable nature of the food, and is represented by the Sloths (*Bradypodidæ*), and also by several extinct forms of gigantic size. The *Entomophaga*, or Insect-eaters, forming the second subdivision of the order, are represented by the Armadillos (*Dasypodidæ*), (Fig. 133), and Ant-eaters (*Myrmecophagidæ*).

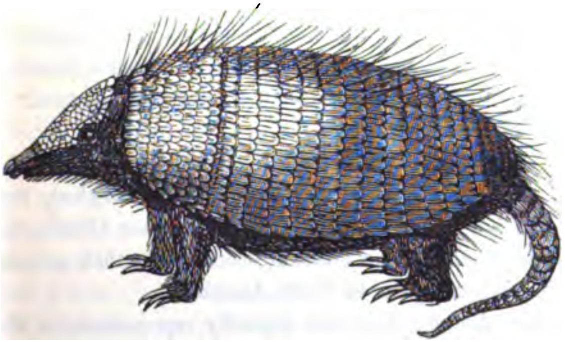


Fig. 133. Edentata.

The Pichiy Armadillo (*Dasypus minutus*); South America.

The skeleton of the Sloths exhibits several features of interest in its adaptation for an arboreal existence, and, conversely, in its unsuitableness for terrestrial progression. The cervical vertebræ, which generally exceed the ordinary number of seven, are exceedingly mobile, and thus admit of a more extensive movement of the head; whilst the extraordinary length of the anterior limbs, and the unusual mobility of the bones of the forearm, together with the powerful claws with which the digits of both limbs are provided, form a most complete series of adaptations to the peculiar life led by these creatures. The posterior limbs also partake of the modification peculiar to the skeleton of the group, in that these members are shortened, and the structure of the ankle-joint, together with the position of the feet, by which they are made available for climbing, render the otherwise unusual mode of progression at once natural and easy.

The stomach exhibits a somewhat complex structure, in that it consists of a double sac, and thus approaches nearly to the character of the compound stomach of the *Ruminantia.*

Of the Sloths the most familiar examples are the Three-toed Sloth, or Ai (*Bradypus tridactylus*), and the *Unau,* or Two-toed Sloth (*Cholœpus* (*Bradypus*) *didactylus*). These forms are confined in their geographical distribution to South America.

The *Entomophaga* are typically represented by the Ant-eaters (*Myrmecophagidæ*) and Armadillos (*Dasypodidæ*). In this section the legs are shortened, the feet being provided with peculiar claws, of service to the animal in the scratching and digging operations by which their particular food is obtained. The *Dasypodidæ* form the first family of this section, and in these forms, which are sometimes known as the *Loricate* Edentata, the back and dorsal region are covered by an armour-casing (Fig. 133), which consists of a series of bony plates or "scutes," developed in the dermal layer of the skin, and of "epidermic" scales also. The bony plates of this dorsal covering, which is thus homologous with the armour-casing of the *Crocodilia*, are arranged to form five plates or shields, protecting the head, neck, shoulders, loins, and hind-quarters; whilst in some instances the tail may also be protected by semicircular rings of bony material. A certain degree of movement is permitted between these various shields, the degree of mobility in some instances admitting of the animal's rolling itself up when irritated or alarmed, after the fashion of our Common Hedgehog, and so presenting an almost invulnerable surface to the enemy. Molar teeth, of the simple structure previously alluded to, exist in great numbers in these forms.

The Ant-Eaters, forming the concluding families of the *Entomophagous* Edentata, are divided into three groups. The (*a*) *Myrmecophagidæ*, or South American Ant-Eaters, are distinguished by the hairy nature of the body-covering, the tail being bushy and elongated, and in some cases prehensile. Teeth are entirely wanting in this family, and the feet are provided with strong claws.

The salivary glands are developed in these forms to an unusual extent, the salivary secretion being of a viscid or gummy nature. The tongue is elongated and protrusible to a great extent, and constitutes, together with the viscid saliva, the means whereby these creatures capture the insects on which they subsist.

The Armadillos and Hairy Ant-Eaters, like the Sloths, are found exclusively on the South American Continent.

The (*b*) *Manidæ*, or Scaly Ant-Eaters, collectively forming the *Squamate* Edentata, are distinguished, as implied by their familiar name, by the imbricated horny scales with which their bodies are covered. These forms, otherwise known as Pangolins, belong exclusively to the Eastern hemisphere, being very generally distributed over Africa and Southern Asia. The disposition of the tongue and salivary glands is essentially similar to that of the preceding family.

The *Orycteropus Capensis*, as solely representing the third family (*c*) *Orycteropidæ*, is confined in its distribution to Southern Africa, where it is termed the "Aard Vark," or "Ground Pig." The body is covered with hairs, the ears being elongated, and thus contrasting with the shortened nature of the structures in the preceding groups. The jaws are provided with "rootless" molar teeth, and the tongue and salivary secretion subserve the peculiar prehensile function observed in the preceding forms. The feet are furnished with powerful claws, of service in the burrowing habits of the animal.

The distributional relations of these forms are of an unusual kind; and, as regards their geographical distribution, we observe their general occurrence in the southern regions of the world, but the strict limitation of individual groups to particular regions of the globe. Their palæontological relations are also deserving of mention—the careful examination of certain fossil remains of gigantic size leading to the classification of these latter forms with the present group. Of these the most noted are the *Megatherium*, *Mylodon*, and *Glyptodon*. The first two of these forms appear to have been most nearly related to the existing Sloths, whilst the latter seems to find its modern but diminutive prototype in the Armadillos (Fig. 133). The body of the *Glyptodon* was covered by a solid carapace, composed of polygonal plates, but which could have admitted of no power of movement such as is possessed by the existing Armadillos. The remains of these fossil *Edentata* have been found in the Recent or Post-tertiary formations of South America.

Order 4. SIRENIA.—The members of the present group are by some authors included with the Whales in the order *Cetacea*, but they appear to be separated from the latter group by certain special and characteristic features. The body and its appendages are, as in the Whales, more or less completely adapted for a marine existence. The hind limbs are wanting, and the under extremity of the body carries a "caudal," or tail-fin, which, however, differs from the analogous appendage in Fishes by being situated transversely, or horizontally, instead of vertically, and in being unsupported by any hard structures or "fin-rays." The pectoral limbs exist in the form of "swimming-paddles" (Fig. 134), and the surface of the body is sparsely covered with bristly hairs. The nostrils are further distinct—provided with valvular membranes, and are situated anteriorly on the snout. The eyes are provided with "nictitating membranes," and the mammary glands are situated on the thorax or chest.

Molar and incisor teeth are present in the *Sirenia*, the former being specially, and apparently alone, developed in the adult state.

The *Sirenia* are represented by the Dugongs (*Halicore*), and Manatees, or Sea-Cows (*Manatus*), (Fig. 134), the former being found on the shores of the Indian Ocean, whilst the latter inhabit the eastern coasts of North America and western coasts of Africa. The *Rhytina Stelleri*, or Northern Manatee, a *Sirenian* of large size, which inhabited the shores of the Arctic Ocean, has become extinct within a comparatively recent date, the last *Rhytina* having been destroyed in 1768.

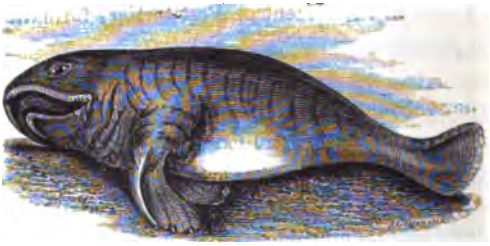


Fig. 134. SIRENIA.
The West-Indian Manatee (*Manatus Americanus*).

The technical name of the group has been suggested by the supposition, that the appearance of these forms, assisted by the lively imagination of mariners, may have given rise to the wondrous tales of sirens and mermaids with which these worthies were wont to regale their willing listeners. The *Sirenia* being estuarine or littoral in their habits, that is, inhabiting the creeks and bays of shallow coasts, or the mouths of rivers, and being said to occasionally assume somewhat of an upright posture, together with the pectoral position of the mammæ; the appearance of these forms may, on these accounts perhaps, and not inaptly, have given rise to the stories above referred to.

Order 5. CETACEA.—This order has been defined as "an order of Mammiferous animals, distinguished as regards outward characters by the absence of hinder extremities, neck, hair, and external ears; and by the presence of a large horizontal caudal fin and the fin-like form of the anterior extremities, the bones of which are shortened, flattened, and enveloped in a thick, unyielding, smooth integument." The adaptation to an aquatic existence of necessity involves a departure to some extent from the ordinary Mammalian type of structure, and in the true Whales, as typically exemplifying this group, the chief points of difference may be conveniently studied.

Externally, the immense bulk of the *Cetacea* attracts attention, as also does the essentially fish-like shape of the body. The regions of the body are indistinctly marked, no true neck being discernible, and the enormous head being apparently united directly to the trunk. Posteriorly, a transverse or horizontally-placed caudal fin terminates the body, the difference between the tail-fin of the fish and that of the *Cetacean* being already alluded to in the case of the *Sirenia*. This fin, further, consists merely of an expansion of the integument, strengthened by a cartilaginous framework. A median "dorsal fin" is sometimes also found, this structure being wanting in the preceding group. Anterior limbs exist in the form of swimming-paddles, but the posterior limbs are undeveloped throughout the order.

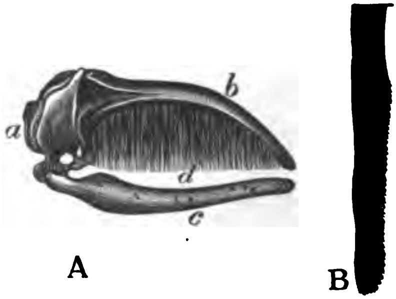


Fig. 135. CETACEA.

A, Skull of Whalebone Whale (*Balæna mysticetus*). *a*, Cranial portion of skull; *b*, upper jaw; *c*, lower jaw; *d*, baleen.

B, Single plate of baleen, showing the fibrous edge by which the plates are united together.

The facial bones are large and extended as compared with the cranial portion of the skull (Fig. 135, A, *a*); and in the Whalebone Whales (*Balænidæ*) the upper maxillary or jaw bones (*b*) bear deep ridges, in which the plates of "whalebone" or "baleen" (*d*) are inserted. These plates, which are flattened, and of elongated shape, are so attached to the palate that the long axis of each depends into the cavity of the mouth;

the entire series of plates thus forming as it were a double median fringe to the upper jaw (*b*). The outer or free edge of each plate is fringed in turn by a fibrous arrangement of the whalebone (Fig. 135, B), binding the entire structure more closely together, and so tending to render it more effective in its purpose, which is undoubtedly that of acting as a "sieve" or "strainer;" preventing substances of large bulk from passing into the contracted œsophagus of the animal, and at the same time serving to retain and entangle the minute organisms upon which these creatures principally subsist. The food of the Whale, therefore, consists principally of *Pteropodous* Mollusca, which exist in countless shoals in the Arctic Seas; and certain members of which group, from the foregoing circumstance, have received the collective title of "Whale's food."

The chief points of interest in the skeleton of the *Cetacea* are comprised under the consideration of the modifications of the vertebral column and pelvic extremities. The cervical segments of the spine, in the present instance, are generally anchylosed together, whilst the dorso-lumbar vertebræ are exceedingly mobile, to admit of the extensive movements of the tail in locomotion. No true sacrum exists, one of the vertebral segments being by some authorities regarded as representing this bone. The skeleton of the anterior members is entirely homologous with that of other and higher *Mammalia*, the clavicles, however, being wanting throughout the order. The bones of the forearm are more or less completely united to each other, and the entire member is enveloped in the thick integument to form a complete and effective natatory organ. Posterior limbs are wanting in the *Cetacea*, the pelvis being represented by two small bones, united to form a V-shaped structure, which is found imbedded among the muscles of the posterior abdominal region. The majority of ribs are not attached to the sternum or breast-bone, these structures articulating superiorly with the transverse processes only of the dorsal vertebræ.

Conical teeth are present in considerable numbers, in all instances save in that of the *Balænidæ* or Whalebone Whales, in which group the presence of teeth is indicated in the fœtal animal; these organs, however, never attaining to any size or perfection, and their place being supplied by the "whalebone" or "baleen" structures previously alluded to.

The stomach appears to be of compound nature, and to exhibit affinities of type to that to be afterwards noticed when treating of the *Ruminantia*.

The respiratory apparatus of these forms as adapted for breathing atmospheric air whilst living an aquatic life, presents several structural features worthy of notice. The nostrils in the *Balænidæ*, situated on the top of the head, and known as "blow-holes," or "spiracles," play an important part in the respiratory process; and the soft palate embraces the conical aperture of the windpipe, and thus forms "a continuous air-passage from the posterior nares (nostrils) to the larynx, on each side of which the food passes." Respiration is thus performed independently of the peculiar mode in which the process of nutrition is carried on in these forms; these animals rising at stated intervals to the surface of the water to inhale a fresh supply of air. At such times the inspired air is ejected from the "blow-holes," and on the true nature of this process much difference of opinion, and many erroneous views, have long continued to exist and be expressed. Thus, the jet of water which is ejected from the nostrils of the *Cetacea* was formerly thought to consist of the water received into the mouth in the process of deglutition. This so-called "spouting," however, from more careful consideration, is found to be caused not by the ejection of the water taken into the mouth in the act of nutrition, but by the heated air of respiration, condensed on exposure to the cold of the atmosphere; together with such superfluous water as may have gained admittance to the nostrils from without, or such superjacent water as may be driven up in the form of spray by the violent nature of the respiratory act.

An external ear is absent, but from the relation of the internal ear to the nasal passages, it is highly probable that the latter apertures subserve, in some measure at least, the purpose of a medium for the collection and transmission of sounds to the auditory centres.

The *Cetacea* in their reproduction exemplify all the characters of the higher *Mammalia;* these creatures suckling their young for a considerable period after birth, and exhibiting for their offspring the greatest care and affection.

The *Cetacea* are divided into three families. The (*a*) *Balænidæ*, or True Whales, form the first of these divisions, and are distinguished by the absence of teeth; by the presence of "baleen" or "whalebone; and by the nostrils being situated on the top of the head.

Of the *Balænidæ*, the typical representative is the Right or Greenland Whale (*Balæna mysticetus*), (Fig. 136, A), and which forms the object of active pursuit for the sake of the "blubber," and "whalebone." The "blubber," or fat, forming a thick coating of the body, serves to preserve an equable temperature, as well as to assist in reducing the specific gravity of the animal. The Right Whale, with the neighbouring species of the Southern Whale (*Balæna australis*), forms

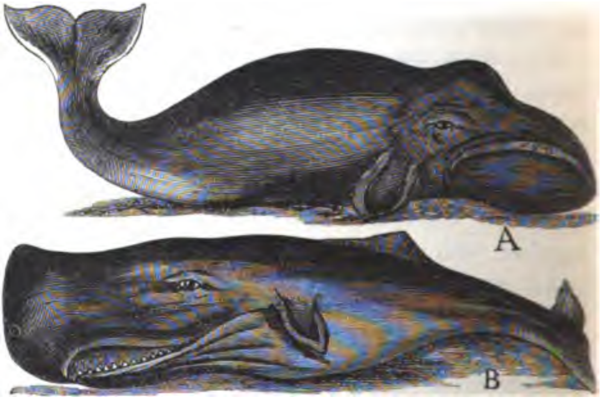


Fig. 136. Cetacea.

A, Right or Greenland Whale (*Balæna mysticetus*).
B, Cachalot or Sperm Whale (*Physeter macrocephalus*).

the section of this family known as the "Smooth" Whales, and which are distinguished by the absence of a dorsal fin. In the "Furrowed" Whales, forming the second section of this family, a dorsal fin exists, and the skin is rough or furrowed; this latter group being sometimes known as the "Finner" Whales. Two genera appear to be included in this section, these being known respectively as *Megaptera* and *Balænoptera*. The familiar name of Rorqual is applied to a species of this latter genus (*Balænoptera Boops*).

The (*b*) *Physeteridæ* or Sperm Whales, sometimes known as the *Catodontidæ*, are distinguished from the preceding forms by possessing a large number of conical teeth in the lower jaw, those of the upper jaw being rudimentary; by the absence of "baleen plates," and by the great relative size of the head, at the anterior extremity of which the united nostrils are situated; this latter character being essentially different from the disposition of these apertures in the *Balænidæ*. The Spermaceti Whale or Cachalot (*Physeter macrocephalus*), (Fig. 136, B), is the most familiar example of the group, this form being hunted for the sake of the oil, spermaceti, and ambergris. The substance known as spermaceti is a peculiar fat, found principally in the cranial cavities of these forms, and much esteemed in the making of unguents, and for other purposes of the pharmaceutist. The ambergris, which is found in the digestive tract of these creatures, obtains its commercial repute as an ingredient in perfumes.

The Sperm Whales inhabit the Southern Seas, and appear to be gregarious in their habits; these forms swimming in companies of from twenty to fifty, each group being technically known as a "school."

The (*c*) *Delphinidæ* or Dolphins, forming the concluding family of the order, are of much smaller size than the members of the preceding divisions. The head is of proportionably smaller size, and usually terminates in a muzzle-shaped snout. The nostrils are united, and are placed on the superior aspect of the head. Teeth exist in both jaws. The Common Dolphin (*Delphinus delphis*); the Porpoise (*Phocæna communis*), inhabiting the European Seas; and the Narwhal or Sea-Unicorn (*Monodon monoceros*), exemplify the three more important genera included in the present family. The latter form is notable, as possessing an extraordinary development of one of the incisor teeth. The lower jaw in the Narwhal is destitute of teeth; the upper jaw of the male containing two abortive molars and two incisors, one of which—the left—is abnormally developed to form a spiral "rostrum" or tusk, which in some instances attains a length of eight or even ten feet. This tusk is developed from a permanent pulp, and, like the tusk of the Elephant, continues to grow throughout life. The females possess rudimentary teeth in the upper jaw, but occasionally the female animal is said to develop a tusk similar to that of the male; whilst in some instances both incisor teeth of the male may be developed in this abnormal fashion. As allied to these animals, mention may here be made of several aberrant forms, which, although differing widely in habits, appear to find their proper place in this family. The *Platanistidæ*, represented by the Loosook or Gangetic Dolphin (*Platanista Gangetica*), is found inhabiting the Ganges, principally at its estuary or delta; whilst the *Inia Boliviensis* is found similarly inhabiting the rivers of Bolivia, at a great distance from the sea.

The fossil remains of a gigantic Cetacean, allied to the existing Toothed Whales, and termed *Zeuglodon*, form the principal feature of interest in the palæontology of the group. This form possessed rooted posterior teeth, and its remains occur in the Miocene formations of Europe and America.

CHAPTER XXX.

PROVINCE C—MAMMALIA.

Classification of Mammalia—(*Continued*).

Order 6. UNGULATA.—Hoofed Quadrupeds.—The order *Ungulata* is of comparatively recent origin, and of compound nature, since it includes within its limits three divisions (*Pachydermata, Solidungula,* and *Ruminantia*), which were formerly, and by some authors still are, accounted as separate and distinct orders. These three latter divisions have in other systems of classification been further altered, and three new sections or sub-orders have been constituted as included in the order *Ungulata.* These three divisions are accordingly known as the *Artiodactyla, Perissodactyla,* and *Proboscidea;* the Pachydermata being by this arrangement rendered obsolete, and being included with the other sections; the Elephants alone being retained, to form a separate section under the name of *Proboscidea.* The *Solidungula* and *Ruminantia* are accordingly merged in the present system, to form two sub-groups of the *Ungulate* order, which stands classified thus:—

Order 6. UNGULATA.	Sub-order (A) *Artiodactyla.*	Sec. 1. Omnivora. Sec. 2. Ruminantia.
	Sub-order (B) *Perissodactyla.*	Sec. 1. Solidungula. Sec. 2. Multungula.
	Sub-order (C) *Proboscidea.*	

The general characteristics of the *Ungulata*, as an order, are sufficiently clear and distinct. The limbs are always four in number, and the perfect and functional toes, which are never more than four to each limb, are generally encased within largely-developed "nails," termed "hoofs." Clavicles are absent throughout the group, the limbs being devoted solely to locomotive purposes.

Sub-order (*a*). ARTIODACTYLA.—This group is distinguished by the even number of the toes, "the third digit of each foot being asymmetrical in itself, and usually forming a symmetrical pair with the fourth digit." The number of the dorsal and lumbar vertebræ, collectively, rarely exceeds nineteen, and is always fewer than twenty-two. The stomach is generally of compound and complex nature; and the horns, when present, exist in pairs, and are supported by a bony central axis or "core."

The sub-order admits of division into two sections, in the first of which—that of the (1) *Omnivora* or *Non-Ruminantia*, three families are included. The (*a*) *Suidæ* or Swine are distinguished by the hairy nature of the skin; by the slender conformation of the limbs; and by possessing the third and fourth toes considerably elongated, these digits being alone available for locomotion, and the second and fifth digits being rudimentary. The nose is of cylindrical form, truncated, and terminated by a cartilaginous tip, serving to protect the organ in the burrowing habits in which these animals indulge. The typical varieties of teeth are present, but the dentition of the family varies considerably. The canine teeth may be greatly developed to form " tusks."

Of this family the representative genus is that of *Sus*, the best known species being the Wild Boar, or Common Hog (*Sus scrofa*), from which, in all probability, our domestic breeds have been derived. In the Indian Archipelago the family is represented by the Babyroussa Hog (*Sus Babyrussa*), remarkable for the length and curvature of the upper canine teeth; whilst in South America the Peccaries (*Dicotyles*) take the place of the European species.

The dental formula of the genus *Sus* is given as follows :—

$$I\ \frac{3-3}{3-3}\ C\ \frac{1-1}{1-1}\ PM\ \frac{4-4}{4-4}\ M\ \frac{3-3}{3-3} = 44.$$

The (*b*) *Hippopotamidæ*, represented solely by the genus *Hippopotamus*, are distinguished by the large size of the head; by the heavy body; by the thickened skin scantily covered with hairs; and by the stunted limbs, each of which is provided with four hoofed toes, the whole of the digits touching the ground in locomotion. The family is exemplified by a single living species, the *Hippopotamus amphibius*, found inhabiting the rivers of Africa.

The dental formula of the adult *Hippopotamus* is—

$$I\ \frac{2-2}{2-2}\ C\ \frac{1-1}{1-1}\ PM\ \frac{3-3}{3-3}\ M\ \frac{3-3}{3-3} = 36.$$

The fossil remains of the *Anoplotherium*, as representing the extinct family (*c*) *Anoplotheridæ*, occur as characteristic fossils of the Eocene and Miocene epochs. This form somewhat resembled the modern Tapirs in appearance, and seems to connect the existing *Suidæ* with the *Ruminantia.*

The (2) *Ruminantia*, or second section of the ARTIODACTYLA, whilst forming a group defined by very natural boundaries, and in all essential points corresponding to the typical structure of the order, also possess a special and distinguishing feature in the faculty of *rumination*, or, in other words, the power of causing the food to regurgitate from the stomach, after deglutition, into the mouth, for the purpose of being masticated for the second time. Besides this special feature in the organisation of the group, several points of minor importance are to be noticed. Thus, the dentition of the group presents certain peculiarities, in that no incisor or canine teeth exist in the majority of instances in the upper jaw—the typical *Ruminants* thus possessing molar teeth only in the upper jaw, to the number of six on either side. The lower jaw generally contains six incisors, two canines—the latter closely resembling the incisors in appearance—and the same number of molars as in the upper jaw ; a space intervening between the canines and molars in the lower jaw, as also seen in the *Solidungula* (Fig. 139). The place of the incisors of the upper jaw is supplied by an anterior thickening of the gum, the incisors of the lower jaw being pressed against this hardened surface in the process of mastication. A deviation from the typical dentition is seen in the *Came-*

lidæ, in which forms the dental arrangement is as follows :—

$$I\,\frac{1-1}{3-3}\;C\,\frac{1-1}{1-1}\;PM\,\frac{2-2}{1-1}\;M\,\frac{3-3}{3-3}=30$$

these animals thus possessing both incisors and canines in the upper jaw.

The metacarpal and metatarsal bones of the two digits (third and fourth) become united in the anterior and posterior limbs respectively, to form the single bones known as "cannon-bones ;" and two rudimentary toes, in addition to the two ordinary and developed digits, are borne on the posterior aspect of the foot. The two ordinary functional toes being enclosed in separate hoofs, and articulated to the "cannon bone" of their respective limbs, produce the well-known "cloven" appearance of the foot. A departure from this structure is witnessed in the Camels, to which reference will be more particularly made hereafter.

The process of *Rumination*, forming the last and chief characteristic feature of the group, may be defined as that faculty by which the food is returned to the mouth after being swallowed, for the purpose of being re-masticated, preparatory to its undergoing the final stages of the digestive process. For the due performance of this function a complicated apparatus exists, consisting of a compound stomach, formed usually by four compartments, the two first of which are to be regarded as corresponding to the "cardiac," or œsophageal portion of the ordinary stomach, whilst the latter two belong to the "pyloric" or intestinal extremity of that organ. The first cavity, to which the term "rumen" or "paunch" is applied (Fig. 137, *b*), is the largest of the compartments, and occupies a considerable portion of the left side of the abdominal cavity. Its internal surface exhibits a roughened appearance, produced by the development in its lining membrane of an immense number of "villi," or small rounded prominences. The second compartment (*c*) is of smaller size, and communicates with the first sac by an opening of considerable magnitude. Its internal surface is divided into a network of hexagonal spaces, and from this appearance it has received the popular name of the "honeycomb," but is more properly termed the "reticulum." The third cavity (*d*), to which the name of "psalterium" or "manyplies" is given, communicates imperfectly with the reticulum (*c*), and also with the gullet (*a*). The "psalterium" is the smallest of the compartments, and has

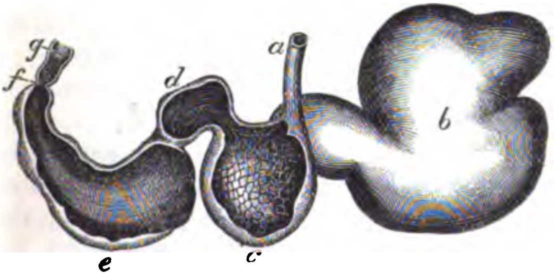


Fig. 137. RUMINANTIA. Stomach of Sheep (*Ovis*) (Huxley).
a, Œsophagus; *b*, paunch or "rumen;" *c*, "reticulum;" *d*, "psalterium;" *e*, "abomasum;" *f*, pyloric aperture of stomach; *g*, duodenum.

also received its name from the peculiar disposition of its lining membrane, which is thrown into longitudinal "rugæ" or folds, somewhat resembling the leaves of a book. The "abomasum," "rennet," or "fourth stomach" (*e*), is, perhaps more than any of the preceding cavities, to be regarded the analogue of the true and ordinary stomach; its mucous or lining membrane is highly vascular, and furnished with glands secreting the gastric juice. The "abomasum" communicates freely with the "psalterium" (*d*), and also with the intestine (*g*); a special valvular arrangement guarding the entrance to the intestinal canal (*f*).

The structure and arrangement of this complicated apparatus being understood, the manner in which its function is performed will be readily perceived. The food, being partially masticated, is passed down the œsophagus (*a*), which terminates at a point midway between the first and second "stomachs." Entering the "rumen" (*b*) the food is moistened, and undergoes some slight preparatory change. From the "rumen" (*b*) the food passes into the "reticulum" (*c*), in which it is supposed to be moulded, by the peculiar reticulated structure of the lining membrane, into rounded masses or boluses, which are next passed into the œsophagus (*a*), and returned to the mouth by a reversed peristaltic action of the œsophageal muscles. Being thus returned to the mouth, the partially-digested food is now thoroughly masticated, and being swallowed for the second time, passes on this occasion into the "psalterium" or third compartment (*d*); the canal communicating with the "rumen" (*b*) being now closed by muscular action, and the food being thus compelled, from the direction of the œsophageal groove, to enter the "psalterium" (*d*). In this latter cavity it undergoes some further change, and is finally subjected in the "abomasum" (*e*) to the action of the true digestive juices. The intestinal canal in the *Ruminantia*, as is the case with all vegetable feeding animals, is of greater relative length than in those forms which feed on an animal diet.

The *Ruminantia* are usually divided into five families:—

(*a*). Family *Camelidæ*.—The Camels and Llamas representing this family are distinguished, as previously mentioned, by the peculiarity of their dentition as compared with that of ordinary *Ruminants*. The structure of the feet also differs from that of other members of the group, in that the palmar and plantar or flat surfaces of the two functional toes are broadly developed; these animals thus walking upon the soles of the feet, and the hoofs of the typical *Ruminants* being represented by mere nail-like structures situated on the dorsal surface of each toe. The rudimentary hoofs of other *Ruminantia* are absent in the *Camelidæ*, and horns are likewise undeveloped throughout the family. The structure of the stomach is also different from the typical structure already described; the gullet opening directly into the "paunch," in the walls of which the so-called "water-cells" are developed; these cells serving as receptacles for water, capable of supplying the wants of the animal in its journeyings over the arid deserts. The red blood-corpuscles in the *Camelidæ* also present an exception to the *Mammalian* type of structure, in that they are elliptical, instead of being oval in shape.

The *Camelidæ* are represented by two groups, confined respectively to the old and new worlds. The Camels of Asia and Africa are represented by the Dromedary or Arabian Camel (*Camelus Dromedarius*), which possesses a single hump only; and by the Bactrian Camel (*C. Bactrianus*), which is distinguished by the possession of two humps.

The Llamas of South America are distinguished by the toes being completely divided, and by the absence of the padded cushion which protects the sole of the foot in the Camels. The "humps" of the Camels are also wanting in the Llamas. The Alpaca (*Auchenia Paco*) of Peru exemplifies a familiar example of the genus.

(*b*). Family *Moschidæ*.—This family is also distinguished by the absence of horns, and by the development of canine teeth in both jaws, those of the upper jaw forming tusks of considerable size in the male animals. The Musk Deer (*Moschus moschiferus*), inhabiting Central Asia, represents this group. It is principally noted on account of a peculiar abdominal sac or gland, secreting the commercial product and perfume known as "musk."

(*c*). Family *Cervidæ*.—The *Cervidæ* or Deer are distinguished by the possession of horns or "antlers," which are characteristic of the males only, the Reindeer forming the solitary exception to this rule. These horns are deciduous, being shed or cast annually, the size and number of branches increasing with the age of the animal. The horns are of solid structure, and thus differ from the structure of those organs in the succeeding family. The epidermis, or outer skin, of the horny core in the *Cervidæ* does not, as in the *Cavicornia*, become modified, to form a "horny epidermic case." The dental formula is exactly similar to that of the *Cavicornia*.

A large number of species of *Cervidæ* are known, their distribution being very general; Australia and Southern Africa, however, being said to possess no representatives of this group. The Stag or Red Deer (*Cervus elephas*); the Roebuck (*Capreolus capræa*); and the Fallow Deer (*Dama platyceros*), are the forms inhabiting Britain; whilst the Elk (*Alces palmatus*), largest of living Deers, and the Reindeer (*Cervus tarandus*), now confined in its distribution to the northern regions of Europe and Asia, exemplify the foreign members of the family.

The *Megaceros Hibernicus*, or Irish Elk, an extinct form, of large size, the remains of which occur plentifully in the recent formations of the British Isles and of Europe generally, appears to have possessed close relations with the Fallow Deer of our own time and country. The antlers must have reached an immense size, several specimens measuring above thirteen feet from tip to tip.

(*d*). *Camelopardalidæ.*—The Camelopard or Giraffe (*Camelopardalis Giraffa*) is the sole representative of this family. It is distinguished by the great length of neck, produced by the simple elongation of the ordinary seven vertebræ. The fore legs are also elongated; the rudimentary toes, as in the *Camelidæ*, are absent; and the horns are of small size, persistent throughout life, and occur in both sexes.

(*e*). Family *Cavicornia*.—The "hollow-horned" *Ruminantia*, comprising the Sheep, Oxen, Antelopes, and Goats, form the most typical examples of the section. The dental arrangement of the group is —

$$I\ \frac{0-0}{3-3}\ C\ \frac{0-0}{1-1}\ PM\ \frac{3-3}{3-3}\ M\ \frac{3-3}{3-3} = 32.$$

The horns are hollow, and consist of processes of the frontal bone, invested by a horny sheath or "epidermic case." The horns, further, are permanent, and are generally possessed by both sexes. The rudimentary toes situated on the posterior aspect of the foot are present in the *Cavicornia*.

The Antelopes (*Antilopidæ*) form the first of the three families into which the group is divided. They closely resemble the Deers, to which, indeed, they are nearly allied; but differ from the *Cervidæ* in the nature and disposition of the horns. The Chamois (*Rupicapra tragus*), inhabiting the mountainous districts of Central Europe, offers a sufficiently familiar example of the group.

The *Ovidæ*, including the Sheep and Goats, form a very large division, remarkable for the number of varieties included within its limits; these varieties rendering the determination of the actual and distinct species a matter of extreme difficulty. The Domestic Sheep (*Ovis aries*) exemplifies the Sheep tribe; whilst the Domestic Goat (*Capra hircus*), distinguished from the Sheep by the possession of a "beard," and by the invariable presence of horns in both sexes, may be taken as representing the characteristic features of the Goats.

The *Bovidæ*, or Oxen, possess horns of simple rounded shape, and which do not assume a twisted or spiral form. Like the Sheep, the various breeds of Oxen have become from time to time so intermingled that it is impossible to give any certain or decided opinion as to the original progenitors of the race. The Buffaloes (*Bubalus*) of America, and the Bisons (*Bonasus*), occurring also in America, and but rarely in Europe, are the chief foreign representatives of the group.

Sub-Order B. PERISSODACTYLA.—In this sub-order of *Ungulata*, the fore-limbs in all, save the *Tapiridæ*, possess an odd number of toes; the hind-limbs being invariably provided with an odd number of digits. The dorsal and lumbar vertebræ are collectively not fewer than twenty-two in number. Horns are not generally present, but when these appendages exist they are single, and placed in the middle line of the skull. In structure, the horns of *Perissodactyla* are wholly "epidermal," and thus consist of a horny sheath, "devoid of a bony core." The stomach is simple in structure. The sub-order is divided into two groups or sections, distinguished by the number of the toes or hoofs. The first of these sections, known as the *Multungula*, possess several hoofed toes; whilst in the *Solidungula* a single toe only is present, this solitary digit being enclosed in a solid expanded hoof.

Two families are included in the *Multungulate* section.

Family (*a*). *Rhinocerotidæ.*—The genus *Rhinoceros* typically represents this family, although some authorities, following the example of Cuvier, include within its limits the *Hyrax*, or "Coney" of Scripture, a form concerning the proper place of which much discussion has taken place. Thus, in certain systems of *Mammalian* classification, *Hyrax* has been included with the *Rodentia;* other observers again have maintained its identity as a transitionary form, connecting the *Ungulata* with the last-mentioned order, to which indeed, in the disposition of its incisor teeth, it bears a great resemblance; whilst a third party, recognising none of these affinities, settle the question by constituting for this single form a separate and distinct order of *Mammalia* under the term *Hyracoidea.* In the present instance it has been thought convenient, apart from technical and anatomical considerations, to retain the *Hyrax* in the family *Rhinocerotidæ;* its affinities with these forms being found chiefly in the nature and disposition of the molar teeth.

The distinctive features of the *Rhinocerotidæ* are found in the nearly equal development of the second, third, and fourth toes of both fore and hind feet, these digits being provided with hoofs. The under surfaces of the metacarpal and metatarsal bones are provided with large cushion-like pads, upon which the great weight of the body is supported. The head is of elongated shape, and provided with a prominent muzzle, which bears on its superior aspect one or two horns, these appendages being situated in the middle line, and borne by the nasal or frontal bones. The horns in the present instance are to be regarded as simple developments of the "epidermis," and are thus closely allied in their nature to hairs. The skin is extremely thick, sparsely covered with hairs, and in the case of the Asiatic species, thrown into characteristic "rugæ" or folds. The upper lip is extremely prominent and protrusible. Teeth of two kinds only—incisors and molars—are present, the former variety being said in some species to be deciduous, and to fall out on the animal attaining the adult age. The dental formula, accordingly, is—

$$I\ \frac{1-1}{1-1}\ \text{or}\ \frac{0-0}{0-0}\quad C\ \frac{0-0}{0-0}\quad PM\ \frac{4-4}{4-4}\quad M\ \frac{3-3}{3-3}$$

Of the members of this group, the Indian Rhinoceros (*R. Indicus*), and the Javan Rhinoceros (*R. Sondaicus*), exemplify the one-horned species; whilst the African Rhinoceros (*R. bicornis*), and the Sumatran species (*R. Sumatrensis*), represent the two-horned forms.

The genus *Hyrax*, represented by several species, of which the Syrian Hyrax or "Coney" (*H. Syriacus*) is the best known species, is distinguished by the absence of canine teeth, and by the peculiar structure of the upper incisor teeth, which grow, like those of the *Rodentia*, from permanent pulps, and possess an anterior layer of enamel. The molar teeth closely resemble those of the *Rhinocerotidæ*. The stomach is of simple structure, and the snout is cleft, as in the *Rodentia*. The toes number four in front; the hind-limbs possessing only three digits.

The dental formula (Fig. 138) is—

$$\text{I}\ \frac{2-2}{2-2}\ \ \text{C}\ \frac{0-0}{0-0}\ \ \text{PM}\ \frac{4-4}{4-4}\ \ \text{M}\ \frac{3-3}{3-3} = 36.$$

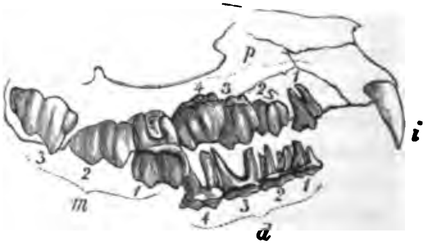


Fig. 138. UNGULATA.

Deciduous and Permanent Dentition of *Hyrax*; *i*, incisor tooth; *m*, 1, 2, 3, molars; *p*, 1, 2, 3, 4, præmolars, succeeding the deciduous or milk-molars (*d*, 1, 2, 3, 4).

The *Hyrax* resembles the Common Rabbit in size and appearance. The body is covered with a coarse fur, and in habits they appear closely to resemble their familiar British representatives. The African species (*H. Capensis*), inhabiting Southern Africa, is familiarly known as the "Cape Badger."

Family (*b*). *Tapiridæ*.—The Tapirs of South America and the Eastern Archipelago represent this group, which is distinguished by the stunted proboscis in which the nose terminates, and by the fore-feet possessing four toes, whilst the hind-feet have only three digits. The skin is soft and well provided with hairs, and the tail is shortened. The dental formula is—

$$\mathrm{I}\ \frac{3-3}{3-3}\quad \mathrm{C}\ \frac{1-1}{1-1}\quad \mathrm{PM}\ \frac{4-4}{3-3}\quad \mathrm{M}\ \frac{3-3}{3-3} = 42.$$

The *Palæotherium*, the remains of which occur as fossils of the Eocene formations of Europe, represents this family in a palæontological aspect.

In the *Solidungula*, as forming the second and remaining section of the *Perissodactyla*, a single toe only—the third—is developed, this solitary digit being encased in a largely-developed solid hoof. The rudimentary toes or hoofs of other *Ungulates* are absent in the present instance. The dental formula (Fig. 139) is—

$$\mathrm{I}\ \frac{3-3}{3-3}\quad \mathrm{C}\ \frac{1-1}{1-1}\quad \mathrm{PM}\ \frac{4-4}{4-4}\quad \mathrm{M}\ \frac{3-3}{3-3} = 44.$$

Between the canine and molar teeth of these forms a considerable interval or "diastema" (Fig. 139) exists, and in this vacant space the "bit," used to guide the

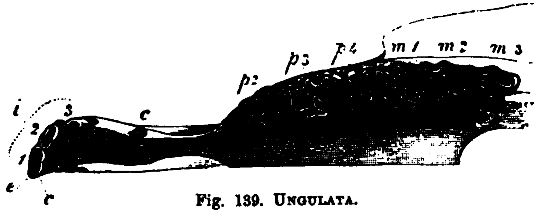


Fig. 139. UNGULATA.

Dentition of the upper jaw of the Horse (*Equus*); *i*, 1, 2, 3, incisor teeth *c*, rudimentary canine tooth; *p*, 2, 3, 4, præmolars; *m*, 1, 2, 3, molars.

horse, is placed. The first præmolar tooth in the *Solidungula* is not preceded by a milk-tooth, and disappears at an early period in the life of the animal. Hence, although reckoned as belonging to the permanent set, this tooth is unrepresented in the illustration (Fig. 139). The canine teeth, which in this group never attain a great size or importance, are present in the males only.

The section includes but a single family, the *Equidæ* or Horses, represented by the two genera; *Equus*, or Horses, and *Asinus* or Asses. The Horses have horny patches or callosities on the inner aspects of the limbs, whilst, in the Asses, these structures exist on the fore-limbs only.

The Horse (*Equus caballus*) exemplifies the first mentioned genus; and of this species many varieties exist. The Asses are represented by the Wild Ass (*Asinus onager*), and by the Zebras and Quaggas of Africa.

Sub-Order C. PROBOSCIDEA.—This sub-order is of comparatively modern construction, and is solely represented by the Elephants, the characteristic "trunk" or "proboscis," into which the nose is prolonged, being deemed a feature of sufficient importance to warrant the isolation of these forms, and their classification in a distinct and separate section. The *Proboscidea* in certain systems of classification are ranked as forming a distinct order of the class, the classification of Owen, who regards them as a section of the *Ungulata*, being adopted in the present instance.

The feet are provided each with five toes, these digits being united by a thick cushion-like integument, which forms a flat surface or sole, on which the great weight of the body is supported. The nose, prolonged into the characteristic "proboscis," forms the chief instrument of prehension in these creatures. This "proboscis" is simply a muscular tube of great flexibility, and capable of very extensive and rapid movement. The nostrils open at its extremity, which is provided with a finger-like process, by means of which the animal is enabled to pick up the smallest and most delicate objects, as well as those requiring great strength for their removal.

The skull is of large size, the otherwise immense weight of the cranium being compensated for by the large size of the spaces or "sinuses" in the frontal bones, which, being filled with air, render the entire structure much lighter and more easily borne.

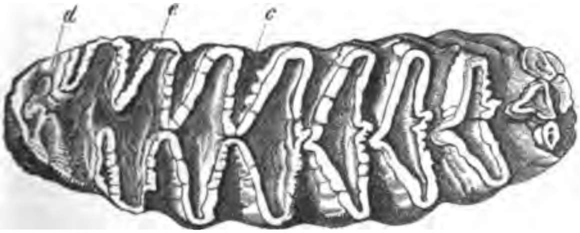


Fig. 140. PROBOSCIDEA.
Upper molar tooth of African Elephant (*Elephas Africanus*), showing the lozenge-shaped arrangement of the enamel plates or ridges.

The dental arrangement of the group presents several highly characteristic features.

Two kinds of teeth only—incisors and molars—are found in existing *Proboscidea*, the dental formula being, according to Owen, I $\frac{2-2}{0-0}$ M $\frac{6-6}{6-6} = 28$. From this formula it will be seen that incisor teeth are present in the upper jaw only, and of these teeth two are abnormally developed to form "tusks," of great length and of peculiar structure; these organs being composed of "cement" and "dentine" only, the "enamel" being very generally absent. These "tusks" spring from a permanent pulp, and thus continue to grow throughout the life of the animal. The incisors alone, in the Elephants, are preceded by milk-teeth. The molar teeth also exhibit a characteristic structure; the crowns of these teeth bearing distinct markings, which differ in form and appearance in the existing species. Thus, in the molars of the African Elephant (Fig. 140), the plates of enamel (*d*) are large, and exhibit a lozenge or diamond shape; whilst in the Indian species (Fig. 141) the plates or

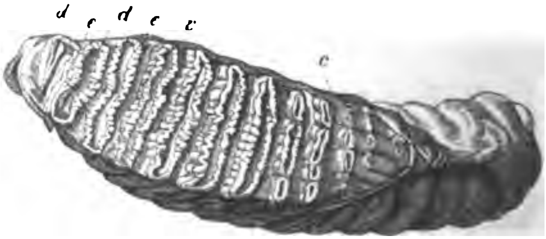


Fig. 141. PROBOSCIDEA.

Upper molar tooth of Indian Elephant (*Elephas Indicus*), showing transverse arrangement of the enamel plates (*d d*), and festooning of their borders (*e e*).

ridges are relatively narrower, arranged in transverse bands or bars (*d*), and exhibit a "festooning" of the edges of the bands (*e*).

The existing *Proboscidea* are represented by two species; the Indian Elephant (*Elephas* (*Euelephas*) *Indicus*), and the African Elephant (*E.* (*Loxodon*) *Africanus*). The former species is recognised by the concave character of the forehead, by the relatively small size of its ears, and by the transverse arrangement of the enamel bands of the molar teeth. The African species is distinguished by its convex forehead, by its large ears, and by the lozenge-shaped disposition of the enamel plates in the molars.

The palæontology of the group rivals that of almost any other division of the animal kingdom, so far as regards the many and interesting features which these forms present in the distributional relations of the past. Three distinct forms may be mentioned as representing extinct *Proboscidea*, the first and oldest of these being the *Dinotherium*, a gigantic form, the fossil remains of which occur in the Miocene formations. Whilst nearly allied to existing Elephants, this form differed from them in several important particulars. Thus, the tusks of the *Dinotherium* sprang from the *lower* jaw; their curvature being in exactly the opposite direction to that of the tusks in existing Elephants. The upper jaw was unprovided with incisors or canines; the only teeth which therefore existed in this form being the molars in each jaw, and, in addition to these, the incisor tusks of the lower jaw. A careful study of the homologies of the *Dinotherium* has led to the conclusion that in all probability this form was semi-aquatic or amphibious in its habits, and that the peculiar arrangement of the tusks "served to detach and tear up by the roots the aquatic plants upon which it fed, as well as for weapons of defence or combat."

The Mammoth (*Elephas primigenius*) forms perhaps the most remarkable of fossil *Proboscidea*. Specimens of this gigantic form have been found, literally packed and preserved, amid Siberian icebergs; its remains having been long sought after for the sake of the ivory of the immense tusks. Our knowledge of the conformation of the Mammoth was rendered both extensive and correct by the discovery of an entire specimen imbedded in the ice, near the mouth of the river Lena, in Siberia, and the skeleton of which is now preserved in the museum of the Academy at St. Petersburg. The skin was covered by a woolly fur of a reddish colour, interspersed with black hairs. The structure of the mola

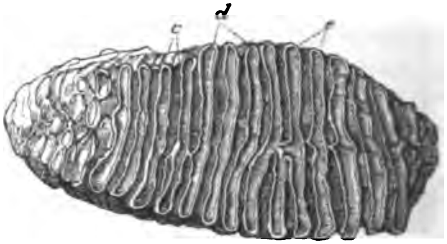


Fig. 142. Proboscidea.
Upper Molar Tooth of Mammoth (*Elephas primigenius*), showing the narrow and closely-set arrangement of the enamel plates.

teeth of the Mammoth (Fig. 142) resembles most closely that of the existing Indian Elephant (Fig. 141), and the tusks were of large or even gigantic size.

The *Mastodon* forms the only remaining genus worthy of notice. This form bears a close resemblance to existing *Proboscidea*. The molar teeth of this latter form exhibited a "tuberculate" structure, and the lower jaw appears to have been furnished with incisor teeth.

The remains of these extinct *Proboscideans*, found very generally distributed over the northern parts of Europe and Asia, and the particular structure of the body-covering, would seem to indicate a wide distribution, in latitudes in which the existing species would be totally unfitted to reside; the general conformation of these forms being specially suited to enable them to withstand the rigour and severity of the Arctic seasons. In another sense, the palæontology of the group is quite as interesting, as affording some hints as to the probable Fauna which co-existed with primitive Man. The remains of these forms being found in close proximity to traces of human handiwork, the inference that they existed contemporaneously with the early human inhabitants of these particular regions is at once safe and justifiable. The remains of the Mammoth and its *Proboscidean* neighbours exist as characteristic fossils of the Tertiary and Post-tertiary or Recent systems of the Cainozoic period.

CHAPTER XXXI.

PROVINCE C—MAMMALIA.

Classification of Mammalia—(*Continued*).

Order 7. **CARNIVORA.**—The distinguishing characteristics of the *Carnivorous* Mammalia are found in the perfection of structure, arrangement, number, and development of the teeth; these organs being present in all their varieties, and exhibiting the typical structure already described. The incisors are in general of small size, and exist typically to the number of six in each jaw. The canine teeth, numbering two in each jaw, exhibit, with the molars, several features of special and distinctive interest. Thus the canine teeth are larger and stronger than in ordinary cases, and are also curved and pointed—features in the structure of these organs which render them admirably adapted for holding and tearing the flesh upon which these animals subsist. The molar teeth generally possess sharp cutting edges, those of the lower jaw approximating closely to those of the upper jaw, so as to form an efficient dividing and cutting apparatus. The præmolars are of conical shape, being inserted in the jaw by single roots only;

whilst of the true molars, the last tooth in the lower jaw and the last but one in the upper jaw are termed "carnassial," "sectorial," or "flesh-teeth;" the name being applied in allusion to the trenchant edges and structure, as pre-eminently adapted for the division of flesh.

In the less typical forms, exemplified by the Bears and their allies (Fig. 145), which exist on a more or less mixed diet, the molars exhibit a "tuberculate" arrangement of their crowns; this latter modification showing the adaptation of the molars, in such cases, for a bruising or triturating, rather than a cutting function.

The movements of the jaws in *Carnivora* are limited in extent, a vertical motion being that to which the muscular movements are principally directed; motion in this direction being well calculated to enable the molar teeth to perform their work in the most effective manner.

The bones of the face are shortened, those of the cranial portion of the skull exhibiting, by their proportions and solidity, an adaptation to the strong muscular attachments, particularly of the jaws. The vertebral column (Fig. 91), as a whole, also evinces in its structure and conformation a conformability to the habits and life of the various members of the group. Thus, in those forms exemplified by the Lion and Tiger, in which the movements are active, the lumbar region is elongated and strengthened, and thus affords a firm base or resisting-point in the movements of springing and leaping, in which these creatures indulge. The clavicles (Fig. 91, *k*) are rudimentary throughout the order.

The structure of the feet presents three characteristic varieties, which have been made use of in the classification of the group. Thus, in the first of the sections into which the *Carnivora* have been divided—that of the *Pinnipedia* or *Pinnigrada*—the limbs are converted into natatorial organs (Fig. 143, C); the toes being united by a web, and the limbs themselves being shortened, flattened, and otherwise adapted to the requirements of an aquatic existence. In the

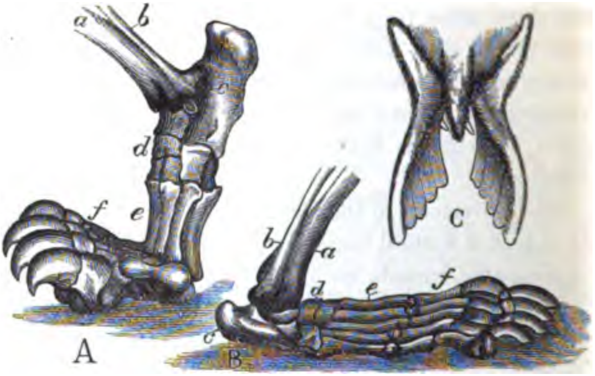


Fig. 143. Carnivora.

Feet of Carnivora. A, Foot of Lion (*Felis*); (*Digitigrada*); *a*, tibia; *b*, fibula; *c*, os calcis, or heel-bone; *d*, other bones of tarsus; *e*, metatarsus; *f*, phalanges. B, Foot of Bear (*Ursus*); (*Plantigrada*). C, Hinder extremities of Seal (*Phoca*); (*Pinnigrada*). References as in first figure.

Bears, as exemplifying the *Plantigrada*, or second section, the entire sole of the foot is placed on the ground in walking; the tarsal and metatarsal bones (Fig. 143, B, *d e*), being elongated, and the phalanges (*f*), entirely resting upon the ground. In the *Digitigrada* (Fig. 143, A), exemplified by the Lions and their allies, the animals walk on the tips of the toes (*f*), the terminal phalanges only resting on the ground, and the heel (*c*), being accordingly drawn upwards on the leg.

In the majority of instances the terminal phalanges are armed with sharp, hooked claws, which, in the typical *Carnivora*, can be retracted or protruded at will.

The order is divided into three groups or sections, distinguished, as above noticed, chiefly by the nature of the progression and consequent structure of the limbs.

Section A. *Pinnigrada* (*Pinnipedia*).—The members of the present section, represented by the Seals and Walruses (Fig. 144), exhibit the farthest departure from the typical *Carnivorous* structure; the modifications of structure being observable in the form of the feet, and in the general conformation of the body, which is thus adapted for a life that, to all intents and purposes, may be termed aquatic. The body is of cylindrical form, and tapers towards the posterior extremity. It is usually covered by a coating of soft downy fur, interspersed with silky hairs. The position of the limbs affords a characteristic feature of the group, the fore-limbs being generally closely connected by integument with the body, whilst the hind-limbs are situated far back, and are turned backwards in nearly the same line or axis as the body. These latter members thus form the chief agents in the progression of these creatures; the fore-limbs being principally used to guide the movements of the animal. The integument of the posterior portion of the body is generally extended to unite the tail and hinder extremities together; a horizontal or transverse fin, analogous to the caudal fin of *Cetacea*, being thus formed.

The three varieties of teeth are present in the *Pinnigrada*, the dentition, however, varying in arrangement throughout the group.

The eyes are generally of large size and expressive, and evince a degree of intelligence and sagacity which would hardly be expected in such animals. A true external ear is usually absent, or, when present, is of rudimentary construction; the auditory passage being protected by a valvular process, which the animal has the power of closing at will. The ears, together with the nostrils, which can also be voluntarily closed, are thus protected when the animal dives under the surface of the water.

Three families are included in this section. (*a*) The *Otaridæ* or Eared Seals form the first of these, and are distinguished by the presence of a rudimentary "pinna," or external ear. These Seals appear to possess, relatively, greater powers of terrestrial progression than the other genera, and from their appearance have been long popularly known as "Sea Lions" and "Sea Bears." They inhabit the Southern and Pacific Oceans; the *Otaria jubata*, or Sea Lion, and *Otaria ursina*, or "Sea Bear," exemplifying the most familiar species of this group. The (*b*) *Trichecidæ* or Walruses (Fig. 144) form the second family, which includes but a single species—the Walrus or Morse—*Trichecus rosmarus*. The distinctive features of the group are found in the peculiarities of the dentition. The dental formula of the adult is :—

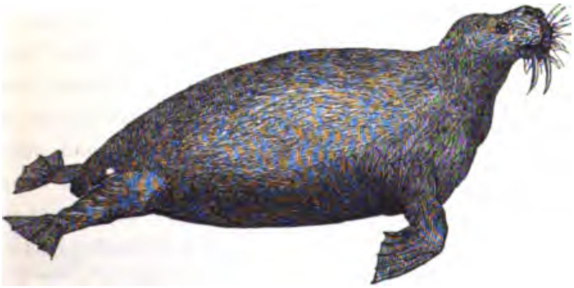


Fig. 144. CARNIVORA.
The Walrus (*Trichecus rosmarus*), (North Sea), showing the upper incisors in the form of tusks.

$$I\ \frac{1-1}{0-0}\ C\ \frac{1-1}{1-1}\ PM \text{ and } M\ \frac{3-3}{3-3} + \frac{2-2}{1-1} = 24.$$

The young animal appears to be provided with six upper and four lower incisors, those teeth being deciduous, and falling out, with the exception of the two outermost of the upper incisors. The upper canines are largely developed, to form two large pointed tusks (Fig. 144), which are curved downwards, attaining in some instances a length of two feet. These tusks spring from a persistent pulp, and so continue to grow during the entire lifetime of the animal.

The Walrus is an animal of heavy build, the body being covered with short hairs of a yellowish hue. These forms appear to be principally herbivorous in their habits, and to live chiefly on seaweed and substances of a similar kind. The tusks are used as a means of defence, and also serve to assist the animal in climbing on the ice. Like the Seals, it is hunted for the sake of the oil contained in the blubber, and also for the ivory furnished by the tusks.

The (*c*) *Phocidæ* or Seals form the remaining family included in this section. An external ear is entirely wanting, and the hind-limbs are stretched out posteriorly, and united by the common integument with the tail. The Seals inhabit the Southern Seas in great numbers; and four species are known to inhabit the British coasts. Of these the most familiar is the *Phoca vitulina* or Common Seal, which is sought after chiefly for the sake of the blubber. In habits the Seals are carnivorous, living principally upon fishes, which they capture with great ease and dexterity. They inhabit the coasts, and rocks near the shore, but rarely venturing upon land, their gait on shore being awkward and laborious in the extreme. The most familiar foreign species are the Harp Seal (*Phoca Greenlandica*), and Great Seal (*P. barbata*), which latter occasionally attains a length of ten feet.

Section B. *Plantigrada.*—In this section, typically represented by the Bears (*Ursidæ*), the entire sole of the foot is applied to the ground in walking. The foot in *Plantigrada* is accordingly elongated (Fig. 143, B), and its several regions are flattened in accordance with the mode of progression of the included forms. The structure of the teeth exemplifies a departure from the ordinary *Carnivorous* type, the crowns of the molar teeth being "tuberculate," or furnished with small tubercles or prominences, evincing an adaptation to a vegetable diet. The dental formula (Fig. 145) of the group is :—

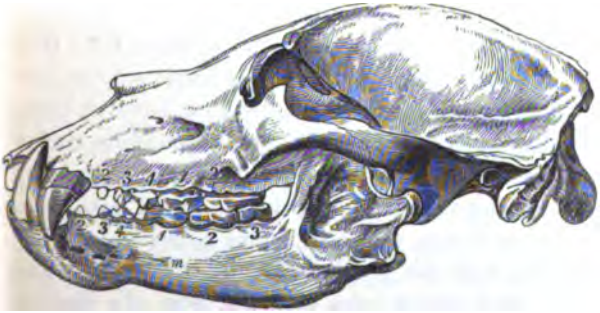


Fig. 145. Carnivora.
Skull of Bear (*Ursus*), showing the dentition.

$$I\ \frac{3-3}{3-3}\ C\ \frac{1-1}{1-1}\ PM\ \frac{4-4}{4-4}\ M\ \frac{2-2}{3-3} = 42$$

Two typical families are included in this section, the *Ursidæ* or Bears, and *Melidæ* or Badgers. The *Ursidæ* have a wide geographical distribution, the family possessing representative members in nearly every quarter of the globe; Australia in this, as in other instances, forming an exception to the almost universal occurrence of these animals. The most familiar forms are the Brown Bear (*Ursus Arctos*); the American or Black Bear (*U. Americanus*); and the Grizzly Bear (*U. ferox*), of the mountainous districts of America. The White or Polar Bear (*Thalassarctos maritimus*) of the Arctic regions, also exemplifies this group; this latter form, however, being carnivorous in its habits. The only extinct form worthy of present mention is the Cave Bear (*Ursus spelæus*), the remains of which, occurring in caves, have been found in Britain, and over Europe generally, in juxtaposition with the remains of allied *Carnivora*. The Cave Bear was of large size, and, from the position and relations of its remains, must have become extinct at a comparatively recent period, geologically speaking.

The Racoons (*Procyon*) and Coatis (*Nasua*) of North America, and the Kinkajous (*Cercoleptes*), inhabiting the tropical regions of America, are generally classed with the *Plantigrada*, although their true position is still a matter of discussion.

The *Melidæ* or Badgers form the remaining family of this section, and concerning the proper place of these forms also, much discussion still prevails. The body is elongated, the legs being stunted, and the molar teeth possess partly trenchant edges. The Common Badger (*Meles taxus*) exemplifies the family in Europe generally, and the Wolverine or Glutton (*Gulo Arcticus*) represents the group in North America. It derives its name from its supposed gluttonous propensities, which, if not wholly without foundation, have certainly been much exaggerated.

The Honey-Badgers of Africa (*Mellivora*) are also included in the present family, their familiar name sufficiently indicating their chief article of diet.

Section C. *Digitigrada.*—These forms walk exclusively on the tips of the terminal phalanges of the feet (Fig. 143, A). The legs are slender, but the muscular system is well and powerfully developed. The *Digitigrada* exemplify the most active of *Carnivorous* forms, their habits being accordingly of the predaceous kind. The group includes many familiar forms, and the families into which it is divided will each require but a passing notice.

(*a*). Family *Canidæ.*—The Dogs and Wolves exemplify this subdivision, which also includes the Foxes (*Vulpes*) and Jackals. Of these forms the Dog and Wolf are nearly allied in most, if not in all, structural points. The fore-feet are furnished each with five toes, the hind feet possessing only four digits. The dental formula entirely agrees with that of the Bears.

(*b*). Family *Felidæ.*—This family includes the most typical *Carnivores*, and is represented by the Lions, Tigers, Leopards, Panthers, Cats, etc. The dental formula is :—

$$I\ \frac{3-3}{3-3}\ C\ \frac{1-1}{1-1}\ PM\ \frac{3-3}{2-2}\ M\ \frac{1-1}{1-1} = 30.$$

(*c*). Family *Hyænidæ.*—The Hyænas, representing this family, may be considered as constituting a connecting link between the *Felidæ* and *Viverridæ*, in which latter forms the special features of the order are less strongly marked. In form the Hyænas bear a strong resemblance to the *Canidæ*, the body, however, in the *Hyænidæ* being depressed towards its posterior extremity, owing to the relative shortness of the hinder legs. The feet are each provided with four toes only. The Striped Hyæna (*Hyæna striata*), inhabiting Northern Africa and Asia, and the Spotted Hyæna (*H. crocuta*), found in the Southern districts of Africa, may be regarded as typically representing the family. In proximity to the remains of the Cave Bear the bones of an extinct species of Hyæna, to which the epithet of "Cave Hyæna" (*Hyæna spelæa*) has been applied, are often found; the palæontological relations of this form coinciding with those already mentioned in the case of the Cave Bear.

(*d*). Family *Viverridæ.*—The consideration of this family introduces us to two groups, which, in certain minor points, differ from the bulk of *Digitigrade* forms. The *Viverridæ* and *Mustelidæ* are accordingly included under the common term *Semi-plantigrada,* since, in walking, these animals apply part of the sole to the ground; the heel, however, as in the other and typical *Digitigrades*, being raised and free from the ground. Whilst thus forming a connecting link between the *Plantigrada* and *Digitigrada*, the *Viverridæ* appear to possess intimate relations with the *Hyænidæ* also. The dental formula is :—

$$\text{I}\ \frac{3-3}{3-3}\ \text{C}\ \frac{1-1}{1-1}\ \text{PM}\ \frac{3-3}{4-4}\ \text{M}\ \frac{3-3}{2-2}\ =\ 40.$$

A feature of special interest in the economy of the *Semi-plantigrada* is the very general presence of an anal pouch or gland, secreting an odoriferous matter, which in certain forms furnishes a substance of commercial repute, whilst in others the secretion is used, from its highly offensive nature, as a means of defence.

The Civets (*Viverra*), inhabiting Africa, exemplify the present family, and are noted for the secretion of the anal gland, known commercially as "civet." The Genette (*Viverra genetta*), inhabiting Southern Europe and Africa, also represents the group; and the Ichneumon (*Herpestes Ichneumon*) of Egypt, famed as the destroyer of the eggs of Crocodiles, Snakes, and other Reptiles, is also included in the present family.

(*e*). Family *Mustelidæ*.—The *Mustelidæ* or Weasels, forming the concluding group of the *Carnivora*, are distinguished by their elongated bodies, and by the possession, in many instances, of anal glands. Nearly all the members of this group enjoy a high commercial reputation, on account of the furs manufactured from their skins, and for which they are accordingly eagerly sought after and pursued.

The Weasel (*Mustela vulgaris*) and Polecat (*M. putorius*) are familiar British representatives of the family; whilst the Stoat or Ermine (*M. erminea*) and the Sable Marten (*M. sibellina*), inhabiting the northern regions of the world, exemplify the foreign and most celebrated members of the group. The Skunk (*Mephitis putorius*) of America, noted on account of the offensive nature of the secretion furnished by the anal glands, is also included in this family; and the Otters (*Lutra*), of which the British Otter (*Lutra vulgaris*) and the Canadian species (*L. canadensis*) are familiar examples, form the only remaining members of the group which may be noticed in the present instance.

Order 8. RODENTIA. — As implied by the term *Rodentia*, the structure and disposition of the teeth form the leading characters by which this group of animals is distinguished. On examining the mouth of a Rodent animal two kinds of teeth only—incisors and molars—are seen to compose the dental apparatus. The incisors (Fig. 146, *i*) attract attention, not only from their large size, but also from the peculiarity of form and disposition. These teeth, usually numbering two in each jaw, are curved in a characteristic manner; those of the upper jaw, to use the words of Professor Owen, describing "a larger segment of a smaller circle; the lower ones a smaller segment of a larger circle." The incisors are deeply rooted in each jaw, their roots passing posteriorly, and under the molar teeth, to terminate in a persistent pulp, by which new depositions of dental substance are being made as continually as the teeth are being abraded and worn away by the process of attrition to which they are subjected. The intimate structure of the teeth further demands attention, inasmuch as, owing to the peculiar arrangement of the dental substance, the loss of tissue consequent on the due performance of their function is equalised and provided for in the most perfect manner. Anteriorly, or on its front surface, each incisor tooth consists of a layer of hard enamel, the posterior part and larger moiety of the organ being composed of the ordinary and softer "dentine," together with "cement." The hardest part of the tooth is therefore its front or anterior portion, and the wear and attrition acting almost solely upon the softer posterior part, tends thus to render the front portion still more oblique, and to pre-

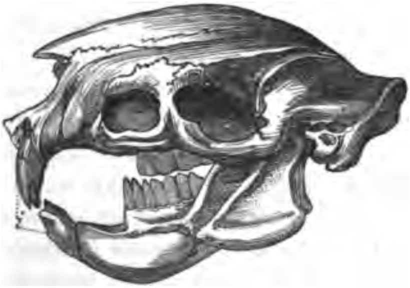


Fig. 146. RODENTIA.
Skull of Porcupine (*Hystrix*), showing the dentition; *i*, incisor teeth.

serve a sharp, chisel-like, anterior edge. And if to this action, the result of which is to preserve a persistent edge anteriorly, we add the continual growth from the pulp, we complete the consideration of a series of actions, in themselves as harmonious and as indicative of design as can well be found in the animal economy.

A considerable interval or "diastema" exists (Fig. 146) between the incisor and molar teeth, the free and unimpeded action of the former teeth being thus secured; whilst the mode of articulation of the lower jaw, by means of an elongated "condyle," or articulating process, permitting of extensive movement from behind forwards, is also well calculated to further increase the efficiency of the dental apparatus. The molars, varying in number from two to six on each side of the jaws, are also of strong construction, and differ in their structure, and in the mode in which they are fixed in the jaw-bones; these teeth being fixed, as in ordinary cases, by roots, but sometimes, like the incisors, continuing to grow throughout life.

The dental formula of the Rabbit, in which, however, two small incisors exist in the upper jaw, behind the true functional gnawing teeth, is as follows, and may be taken as almost typical of the group:—

$$\mathrm{I}\ \frac{2-2}{1-1}\ \mathrm{C}\ \frac{0-0}{0-0}\ \mathrm{PM}\ \frac{3-3}{2-2}\ \mathrm{M}\ \frac{3-3}{3-3}\ =\ 28.$$

The feet are generally each provided with five toes, the great toe or "hallux" of each foot resembling the other digits in size and conformation. The clavicles, whilst usually present, are at the best but imperfectly developed, and in some instances, as in the Guinea-pigs, they may be altogether wanting. The surface of the brain presents a special peculiarity of structure, in that it is almost entirely destitute of convolutions; the cerebellum or lesser brain being left almost entirely uncovered by the cerebrum or brain proper. These characteristics would seem to indicate a near approach, in the characters of the nervous system at least, to the *Implacental* Mammalia, with which group the *Rodentia* are by some authorities said not to be without intimate relations.

The order is divided into numerous families, the more important of which need only be briefly referred to.

(*a*.) Family *Leporidæ*.—The members of this group, represented by the Hares and Rabbits (*Lepus*), are distinguished by the possession of two additional and small incisors in the upper jaw. The dental formula has already been given.

(*b*.) Family *Cavidæ*.—The Cavies are distinguished by the possession of a hairy body, and by the absence or very rudimentary condition of the tail. The limbs are also of more equal size than in the preceding group. The feet are provided with three toes only, and the nails assume a hoof-like character and form. The Capybara (*Hydrochærus capybara*) of South America, and the Guinea-pig (*Cavia aperæa*), furnish examples of this family.

(*c*.) Family *Hystricidæ*.—The Porcupines (Fig. 146) are distinguished by the peculiar nature of the body-covering, which consists of bristly hairs, interspersed with spines. The molar teeth number eight in each jaw. The Common Porcupine of Southern Europe (*Hystrix cristata*), and the North American species (*Erethizon dorsata*), exemplify the group. The South American genus *Cercolabes* possess an elongated, prehensile tail, assisting these animals in their ascents and movements among trees, their life being thus principally arboreal.

(*d.*) Family *Castoridæ.*—The Beavers, representing this division, are adapted for an amphibious life, the toes of the hinder feet being united by a web or membrane. The enamel of the molar teeth exhibits a series of convolutions, giving to these teeth a highly complicated and characteristic appearance. The feet are provided each with five toes, and the character of the tail, which is generally of large size and flattened, also affords a distinctive feature of the group. The Beaver (*Castor fiber*) has, from the unremitting pursuit with which it has been followed, become nearly wholly exterminated in Europe, and its American neighbours are from the same cause said to be growing both scarce and rare. These forms are sought after for their fur, and also on account of the substance secreted by the anal sacs or glands, which is used in medicine, and known as "castoreum." The Beavers are social in their habits, living in communities, and constructing on the rivers they inhabit large dams, and habitations or "lodges," formed of the stems and branches of trees, which they are said to fell by the gnawing action of the incisor teeth.

The Musquash of North America (*Fiber Zibethicus*), and Coypu of South America (*Myopotamus coypus*), are also included in this family.

(*e.*) Family *Muridæ.*—In the Rats and Mice, as forming typical examples of this family, the tail is elongated, and usually destitute of hairs. The fore feet are provided with four toes, and an abortive thumb; the hinder feet possessing five toes. The clavicles are well developed in the present instance. The Rats and Mice, forming a single genus (*Mus*), are divisible into a large number of species. Of the Rats, the most familiar are the Brown Rat (*Mus decumanus*), and the Black Rat (*Mus rattus*); whilst of the Mice, the best known species are the Common Mouse (*Mus musculus*), the Harvest-mouse (*M. messorius*), and the Field-mouse (*M. sylvaticus*). The Lemmings (*Myodes*), found inhabiting Northern Europe, are allied to the Rats, and are noted principally for their migratory habits, and for the persistency with which they pursue their way; preserving in their route an unbroken course, and crossing in their journeys rivers and lakes of considerable breadth.

(*f.*) Family *Dipodidæ.*—The Jerboas somewhat resemble diminutive Kangaroos in appearance, the hind-legs being, as in these *Marsupials*, greatly elongated. They inhabit Asia, Africa, and North America, and live in communities. The most familiar species is the Egyptian Jerboa (*Dipus Ægyptius*).

(*g.*) Family *Myoxidæ.*—The Dormice represent this group, the proper position of these forms being still a matter of discussion. By some authorities they are included in the *Insectivora*; but, on the whole, they may perhaps be more properly regarded as Rodents. The Common Dormouse (*Myoxus avellanarius*) exemplifies the family.

(*h.*) Family *Sciuridæ.*—The Squirrels possess an additional (fifth) molar in the upper jaw (M $\frac{5-5}{4-4}$); these teeth being of very simple structure. The pollex or thumb of the fore-feet is nearly opposable to the other digits; a feature bringing these forms into relation with the *Quadrumana.* The large and bushy proportions of the tail present a well-known feature of these animals. The Common Squirrel (*Sciurus vulgaris*) occurs throughout Europe, and also in North America, which latter province may be considered the chief area of the distribution of these forms. The Flying Squirrels (*Pteromys*) of Southern Asia are specially characterised by the presence of a broad fold of membrane extending along the sides of the body, and between the fore and hind legs, and which serves to assist them in a pseudo-aerial progression from tree to tree; although the term flight can hardly be applied to the power of motion in the air with which the membrane endues its possessor. The Marmots (*Arctomys*) of northern latitudes are also included in this family.

The *Rodentia* thus possess a very wide distribution in space, the island of Madagascar being the only province of any size or importance in which there are no indigenous Rodents. Fossil examples of the order first occur in the Eocene formations of the Tertiary period.

CHAPTER XXXII.

PROVINCE C—MAMMALIA.

Classification of Mammalia—(*Continued*).

ORDER 9. INSECTIVORA.—The *Insectivorous* Mammalia exhibit very intimate relations with the *Rodentia*, the distinctive features of the present group, however, consisting in the uniform nature of the teeth; in the presence of more than four incisors in each jaw; and in the conformation of the molar teeth, the crowns of which are provided with small eminences or "cusps," suited for crushing the insects on which these forms chiefly subsist. The *Insectivora*, in their walking, are either plantigrade, or partly so, and the clavicles are now well developed. The cerebral hemispheres, as in the preceding order, are nearly destitute of convolutions. The similarity in form, structure, and appearance of the teeth, renders the determination of their homologies an exceedingly difficult matter.

Three families are included in this order, which, according to some authorities, also contains the aberrant genus, *Galeopithecus*, or Flying Lemurs, and accepting this view, these latter forms may be held as constituting a fourth family, that of the *Galeopithecidæ*.

The first family, that of the (*a*) *Talpidæ*, or Moles, is distinguished by the shortened body and pointed muzzle; by the rudimentary nature of the eyes; by the absence of external ears; and by the strong claws with which the toes are furnished. The fore limbs in the present instance greatly exceed the posterior members in size. The Common Mole (*Talpa Europæa*) is the sole British representative of the group; the most noted of the foreign species being the African Golden Mole (*Chrysochlorus aureus*), so named from the iridescent hues and lustre of its fur.

In the (*b*) *Soricidæ* or Shrew-Mice, forming the second family, the eyes and ears are perfectly developed. The Common Shrew (*Sorex araneus*), and the Water Shrew (*S. fodiens*), both inhabit Britain. The Shrews include the smallest of Mammalian forms, and possess a very wide distribution. The canine teeth are absent in this group.

The (*c*) *Erinaceidæ* or Hedgehogs exceed other Insectivora in size, and are distinguished by the spiny aspect of the dorsal body-covering, which consists of spiny hairs; the ventral surface being covered with ordinary hairs. The animal possesses the power of rolling its body upon itself, so as to form a ball, and thus presents a bristling array of spines as a defensive front. This process is effected by means of a specially developed cutaneous or skin muscle, the chief fibres of which are collectively known as the "orbicularis panniculi." The dental formula is:—

$$\mathrm{I}\ \frac{3-3}{3-3}\ \mathrm{C}\ \frac{0-0}{0-0}\ \mathrm{PM}\ \frac{4-4}{2-2}\ \mathrm{M}\ \frac{3-3}{3-3} = 36.$$

The Common Hedgehog (*Erinaceus Europæus*) is the only British species, but the family appears to be represented in Asia and Africa also.

The (*d*) *Galeopithecidæ*, or Flying Lemurs, found inhabiting the Indian Archipelago, are, according to the most trustworthy sources, regarded as "aberrant *Insectivorous* forms." The chief points of abnormal structure in these animals consist, firstly, in the presence of a "patagium" or "flying-membrane," somewhat analogous to that observed in the case of the Flying Squirrels, and in the succeeding and higher order also. The limbs are elongated, and are connected together, and to the neck, trunk, and tail, by the patagium; this membrane also uniting the digits of the posterior limbs. The patagium of the *Galeopithecidæ* differs from that of the Bats in being covered on both sides with hair. The possession of this membrane enables the creature to effect flying leaps from tree to tree, as in the case of analogous forms. The dentition is somewhat peculiar, the outermost incisor teeth of the upper jaw being provided with double roots, "a peculiarity which," to use Huxley's expression, "is not known to occur elsewhere." The dental formula is :—

$$\mathrm{I}\ \frac{2-2}{3-3}\ \ \mathrm{C}\ \frac{1-1}{1-1}\ \ \mathrm{PM}\ \frac{2-2}{2-2}\ \ \mathrm{M}\ \frac{3-3}{3-3} = 34.$$

These forms, by some authorities included in the *Quadrumana*, are distinguished from the members of that group principally by the fact that the thumbs (pollex) and great toes (hallux) are inopposable to, or cannot be brought in contact with, the tips of the other digits, so as to constitute the chief distinctive and essential feature of a "hand."

Order 10. CHEIROPTERA.—This group has been shortly defined as "an order of Mammiferous Quadrupeds, consisting of such as have a generally Insectivorous type of dentition, with the extremities connected together by an aliform or wing-like expansion of the integuments, for the purpose of flight." The

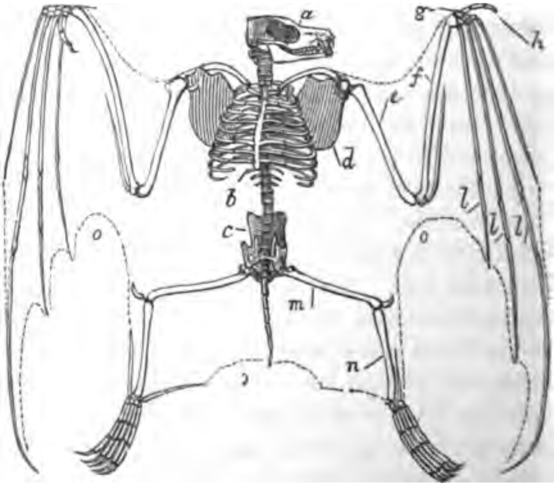


Fig. 147. CHEIROPTERA.

Skeleton of Bulldog Bat (*Noctilio mastivus*); Ecuador. *a*, skull; *b*, thorax; *c*, pelvis; *d*, scapula; *e*, humerus; *f*, radius, to which the rudimentary ulna is articulated; *g*, carpus; *h*, thumb digit; *l*, *l*, *l*, elongated metacarpus and phalanges; *m*, femur; *n*, tibia, with rudimentary fibula; *o*, *o*, *o*, patagium, represented in outline.

special features of this group are therefore readily recognisable, and are found in those modifications of structure which enable the creature to exchange a terrestrial for an aerial life. The osteology of the anterior members, and the disposition of the "patagium," accordingly form the chief points to which attention may be directed.

The sternum or breastbone (Fig. 147) is specially developed; its upper portion—"manubrium"—being especially large, and extended to form a support and *point d'appui* for the clavicles. The anterior extremities attract attention by their great relative length, the humerus (Fig. 147, *e*) and forearm (*f*) being elongated; the ulna being imperfectly developed, and the radius chiefly supporting the wrist. The arm thus possesses little or no power of rotation, a description of movement totally useless and inconvenient in the exercise of the power of flight. In the metacarpus and phalanges (*l*, *l*) the acme of development is reached. The bones of the fingers are greatly elongated, the thumb (*h*), however, being much shorter than the other digits. The third, fourth, and fifth fingers are destitute of nails; the second is occasionally unprovided with these appendages, but the nails of the thumbs are specially developed to form claw-like processes, by means of which these animals suspend themselves from fixed objects. The nail-less fingers are composed of two phalanges only.

The posterior limbs (*m*, *n*) are proportionable in size, and do not exhibit any peculiarities worthy of special notice, save that the fibula, like its prototype of the upper limb, is of rudimentary construction. The digits of the feet are all provided with nails; the nail of the hallux being similar in conformation to that of the other toes.

The "patagium" or "flying-membrane" (Fig. 147, *o o*) is of leathery consistence, and almost entirely destitute of hairs. It extends along the sides of the body, thus uniting the fore and hind limbs, and also connects the elongated digits of the fore limb; whilst it may also be stretched between the hind limbs and tail—the latter member varying in development throughout the order.

The body is generally covered with a short fur. The external ears are well developed, the large size of these organs giving to certain species of Bats the familiar and peculiar appearance of these forms. The sense of touch is in all probability subserved by the "patagium," together with certain leaf-like appendages of the ears and nose. The sense of sight in all the Bats is exceedingly acute.

The *Cheiroptera* are for the most part nocturnal in their habits, and the majority of species would appear to hybernate during the winter months and colder seasons of the year.

The *Cheiroptera* are divided into two sections, distinguished by the nature of the food. In the first of these sections, that of the *Frugivora* or Fruit-eating Bats, a single family, the *Pteropidæ* or Fox-Bats, is included. The familiar name of these creatures is derived from the resemblance of the head to that of a dog or fox. The jaws are more elongated than in other

Bats, and canine and incisor teeth are present in both jaws. The second digit of the hand bears a distinct nail; and the tail is of moderate or rudimentary dimensions. The nose is destitute of foliaceous appendages; the external ears being of the ordinary size and form. The *Pteropidæ* are distributed very generally over the warmer and tropical regions of the world; the species selected for illustration being the Kalong or Javan Fox-Bat (*Pteropus edulis*), (Fig. 148, B).

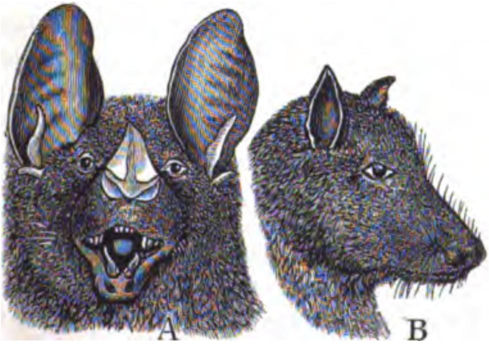


Fig. 148. CHEIROPTERA.
A, Head of Vampire Bat (*Phyllostoma spectrum*).
B, Head of Kalong or Fox-Bat (*Pteropus edulis*).

The *Insectivora*, or Insect-eating Bats, forming the remaining section of the order, comprise three families, of which the (*a*) *Vespertilionidæ* include the most familiar British forms. The Common Bat or Pipistrelle (*Vespertilio pipistrella*), and the Long-eared Bat (*Plecotus auritus*), exemplify this family, in which the molar teeth are furnished, like those of the true *Insectivorous* Mammals, with cusps or prominences, suited for crushing their insect-prey. The tail is well developed, and generally united by an "inter-femoral" membrane with the hinder limbs. The ears are large, and occasionally furnished with leaf-like folds, but the nose is destitute of foliaceous appendages.

The (*b*) *Rhinolophidæ*, forming the second family, are distinguished by the possession, in addition to the characters of the *Vespertilionidæ* above mentioned, of leaf-like appendages attached to the nose. These forms are sometimes known as "Horse-shoe Bats," deriving their familiar appellation from the conformation of the nasal appendages referred to above. These Bats are typically found in tropical climates, but two species appear to inhabit Britain; these being the Greater Horse-shoe Bat (*Rhinolophus ferrum-equinum*), and Lesser Horse-shoe Bat (*R. hipposideros*).

The third and last family, that of the (*c*) *Phyllostomidæ*, includes the most noted of these forms, the so-called Vampire Bats (Fig. 148, A). The canine teeth are of large size. Nasal appendages are present, and the ears, which are of comparatively moderate size, are also provided with membranous appendages. The tail in some cases is rudimentary, but in others is well developed. The Vampire Bat (*Phyllostoma spectrum*) (Fig. 148, A) is the typical representative of the group, and has attained a somewhat evil reputation from its alleged habit of attacking sleeping travellers and sucking their blood. Although these Bats are known to attack horses and cattle, it is but rarely that man is assailed. The effect of the bite is merely to weaken the system from loss of blood; no poisonous effects being known to accrue from the attack of these creatures. A large saccular appendage is found in certain members of the group, attached to the anterior portion of the stomach, and into this pouch-like structure the blood sucked by those animals is supposed to pass and accumulate. This structure calls at once to mind the analogous disposition of parts in the leech.

CHAPTER XXXIII.

PROVINCE C—MAMMALIA.

Classification of Mammalia—(*Continued*).

Order 11. QUADRUMANA.—The term *Quadrumana*, applied to this order, indicates a distinctive and characteristic feature of the forms comprised within its limits. This feature consists in the power of opposing the pollex, thumb, or outermost digit of the hand, and hallux, great toe, or outermost digit of the foot, to the other digits of the hand and foot, thus converting the limbs into prehensile organs, and constituting the animal truly "quadrumanous," or "four-handed." The Monkeys, Apes, and Lemurs represent this order, the members of which exhibit in their organisation a graduated series of forms, allied, on the one hand, to the preceding orders, and approaching nearly, on the other hand, to the peculiar characteristics which distinguish the highest of animals—Man himself.

The peculiar and diagnostic features of the group are found in the dentition, in the conformation of the skull, and in the disposition of the limbs. The teeth exist generally in very perfect array, the incisors in no case numbering more than four in each jaw, whilst molars are invariably present, and canines in every case save one. The teeth are further interrupted by a "diastema" or interval, a continuous series of teeth being found only in Man. The facial elements of the skull, in the generality of cases, preponderate over the cranial portion, the bones of the face in most instances being prolonged into a prominent muzzle. Whilst in the most typical forms both fore and hind feet are provided with opposable "thumbs," many species are provided with these opposable digits on the hinder feet only; the individual cases in which this peculiarity occurs being noticed under the classification of the group. The tail varies in its development, being found in some species of considerable length; whilst in others, and particularly in the higher Apes, it is of very rudimentary and abortive structure.

The remaining general characters which may be considered worthy of notice are found in the invariable presence of clavicles, and in the number of developed mammary glands, which generally exist to the number of two, these being pectoral or thoracic in position.

The classification of the *Quadrumana* is, as might be expected, a matter concerning which much difference of opinion exists—the number of forms included within its limits, the close resemblances presented by these forms, the continual addition of new species, and above all, the intimate relations of this group with the succeeding order, tending to render the clear terminology and arrangement of the *Quadrumana* a most difficult, and, in many cases, an unsatisfactory proceeding. Thus, by some authors, we have the *Quadrumana* and *Bimana* included in a common order, to which the term *Primates* is given; this order being divisible into the three sub-orders of *Anthropidæ* (Man); *Simiadæ* (Apes); and *Lemuridæ* (Lemurs). A modification of this system subdivides the *Primates* into the *Lemuroidea*, including the Apes and Lemurs, and the *Anthropoidea*, including Man. The intimate taxonomy of the order itself, and

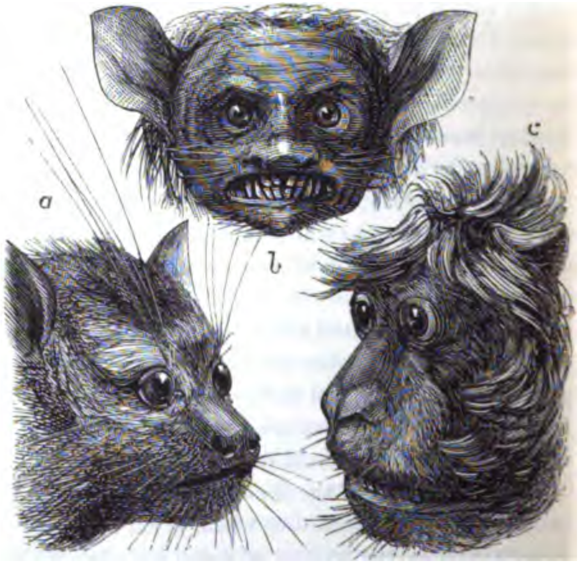


Fig. 149. QUADRUMANA.

a, *Strepsirhina*; Head of Aye-Aye of Madagascar (*Cheiromys Madagascariensis*). *b*, *Platyrhina*; Head of White-necked Marmoset (*Jacchus bicolor*). *c*, *Catarhina*; Head of East Indian Red Monkey (*Macacus rufescens*).

apart from its relations with the succeeding group, has also been subjected to much variation, but ordinarily the *Quadrumana* are divided into two groups—the *Prosimiæ*, or Pseudo-Apes, including the Lemurs; and the *Simiæ*, or True Apes, represented by the ordinary *Quadrumanous* forms. According to Owen the order is divided into three sections, distinguished by the structural peculiarities, and also in great measure by the geographical distribution of the included forms. Each of these three groups, therefore, merits some distinction and description.

Section A. *Strepsirhina; (Prosimiæ).*—As implied by the term *Strepsirhina*, the nostrils of the forms included in this division are curved or twisted (Fig. 149, *a*). The fore and hind feet are provided with five toes each, the second digits of the hinder feet being provided with claw-like nails. The fourth digit, especially of the hinder feet, is generally elongated. The distributional area of this section is found in the Eastern Coast of Africa, chiefly in Madagascar; but also in the Indian Archipelago.

Three families represent this section. The (*a.*) *Lemuridæ* or Lemurs are distinguished by the elongated nose and jaws, the term "Fox-nosed Monkeys" being sometimes applied to them on this account. The fore limbs are shorter than the posterior members, the thumbs of both fore and hind feet being opposable. The second digit of the foot bears a claw-like nail, and the fourth digit is of great relative length, as compared with the other toes. The tail is long, but never prehensile. The dentition is indicative of an insectivorous diet, and the dental formula is :—

$$\text{I}\ \frac{2-2}{2-2}\ \text{C}\ \frac{1-1}{1-1}\ \text{PM}+\text{M}\ \frac{5-5}{5-5}\ \text{or}\ \frac{6-6}{6-6}$$

The Lemurs are confined in their distribution to the island of Madagascar.

(*b.*) Family *Nycticebidæ.* The Lories and Pottos of Java, Ceylon, and the Eastern Asia, represent this family, which is distinguished chiefly by the small size of the ears and tail. They appear to be nocturnal in their habits, and are closely allied to the True Lemurs in structure and appearance.

(*c.*) Family *Cheiromydæ.* The "Aye-Aye," or *Cheiromys* of Madagascar (Fig. 149, *a*)—so named from its peculiar cry—is the sole representative of this group. The thumbs of the fore feet are not wholly opposable, the nail of the pollex being claw-like, and thus resembling the conformation of these structures in the other digits. The third digit of the hand is greatly elongated; the hallux of the hinder feet being perfectly opposable to the other digits. The tail is long, and of bushy conformation; the ears being of large size. The dentition indicates an affinity to the *Rodentia;* canine teeth being wanting, and the incisors growing from persistent pulps, and being provided with an anterior layer of enamel. The dental formula would appear to be :—

$$\text{I}\ \frac{1-1}{1-1}\ \text{C}\ \frac{0-0}{0-0}\ \text{PM}+\text{M}\ \frac{4-4}{4-4}$$

The *Simiæ* or True Apes include the two remaining sections.

Section B. *Platyrhina.*—The *Platyrhine* or New World Monkeys are characterised by the breadth of the nose, the nostrils being placed far apart and widely separated (Fig. 149, *b*); by the possession of opposable thumbs on the hind feet only; and, lastly, by the presence in the majority of instances of an elongated prehensile tail. Cheek-pouches and "natal" or "ischial" callosities are wanting throughout this group. In their distribution the *Platyrhina* are confined to South America. Two families are included in this section. The (*a*) *Hapalidæ* or Marmosets (Fig. 149, *b*), inhabiting Brazil, are distinguished by their small size, and by the non-prehensile tail, which is large and bushy, the body being covered with a woolly fur. The Marmosets are plantigrade, and never assume the erect posture, their progression being "habitually quadrupedal." The dental formula is :—

$$\frac{2-2}{2-2}\ \mathrm{C}\ \frac{1-1}{1-1}\ \mathrm{PM}\ \frac{3-3}{3-3}\ \mathrm{M}\ \frac{2-2}{2-2} = 32.$$

The (*b*) *Cebidæ*, forming the remaining family, are represented by the Spider Monkeys (*Ateles*); Capuchin Monkeys (*Cebus*); and by the Howling Monkeys (*Mycetes*), of Tropical America. These forms occasionally assume the erect posture, their distinctive feature being the possession of prehensile tails, which serve as material aids to these forms in the eminently arboreal life they lead in the tropical forests of Brazil. The dental formula is :—

$$\mathrm{I}\ \frac{2-2}{2-2}\ \mathrm{C}\ \frac{1-1}{1-1}\ \mathrm{PM}\ \frac{3-3}{3-3}\ \mathrm{M}\ \frac{3-3}{3-3} = 36.$$

Section C. *Catarhina.*—The *Catarhine* or Old World Monkeys are distinguished by the oblique position and close approximation of the nostrils (Fig. 149, *c*); by the presence of cheek-pouches, and also of hard callosities on the nates, or protuberances of the "ischial" (pelvic) bones; by the opposable nature of the thumbs of both fore and hind feet; and by the non-prehensile and often rudimentary nature of the tail. The dental formula resembles that of Man, but the teeth are not arranged in a continuous series; an interval or "diastema" breaking the continuity of the dental margin. The incisors are generally largely developed, whilst the canines usually protrude beyond the jaw. In geographical distribution they are, with one exception, confined to Asia and Africa;—the Macaques having a representative species, residing on the Rock of Gibraltar.

The section is divided into two groups, in the first of which, that of the (*A.*) *Cynomorpha*, distinguished by the presence of natal callosities and of cheek-pouches, and by the comparative length of the tail, two families are included. The (*a*) *Semnopitheci*, represented by the *Semnopithecus entellus*, or Sacred monkey of India, form the first of these families, and are distinguished chiefly by the elongated tail, in addition to the presence ot cheek-pouches and callosities. In the genus *Colobus*, included in this family, the "pollex" or thumb of the fore feet is rudimentary or wanting. The Macaques (*Macacus*), (Fig. 149, *c*) also exemplify the present group. In the (*b*) *Cynocephali* the Baboons of Africa are included. The tail in these forms is short or rudimentary; the natal callosities being large, and usually of a bright colour. The Mandrill (*Papio Maimon*), also represents this group, and is distinguished by the bright blue colour of the cheek-ridges.

The remaining section of the *Catarhina*—that of the (*B.*) *Anthropomorpha*, or Man-like Apes—includes those forms which most nearly approach the human type of structure. The tail is rudimentary; cheek-pouches are wanting, and natal callosities are not invariably present. The fore limbs exceed the posterior limbs in length; a semi-erect posture being occasionally assumed by these forms, which are essentially arboreal in their habits. The thumbs of both fore and hind feet are opposable to the other digits.

Three genera are included in this order. The (*a*) Gibbons (*Hylobates*) exemplify the first of these; they possess natal callosities, and the arms are greatly elongated. The Siamang of Sumatra (*Hylobates syndactylus*) also exemplifies this genus. The (*b*) Orang (*Pithecus*), confined in its distribution to the Eastern Archipelago, represents the second genus; this form possesses no cheek-pouches, and ischial callosities are also wanting. The third and concluding genus (*c*) *Troglodytes*, includes the Chimpanzees and Gorillas; both of these forms inhabiting the central portion of Western Africa. In the Chimpanzee (*Troglodytes niger*) the arms are relatively shorter than in the other genera. The Gorilla (*T. Gorilla*), (Fig. 150, B) is one of the largest of the *Quadrumana*, attaining a height of from four to nearly six feet. The existence of the Gorilla has only been ascertained of late years, the labours of Mons. Paul de Chaillu having been mainly instrumental in adding to our knowledge of this form, which most nearly, of all the Apes, approaches to the human type of structure. The Gorilla, to use Huxley's words, most nearly approaches man "in the proportions of the leg to the body, and of the foot to the hand; further, in the size of the heel, the curvature of the spine, the form of the pelvis, and the absolute capacity of the cranium." It is, however, curious to observe, that in the annals of Hanno, the Carthaginian voyager, dating from or about the year 570 B.C., a species of gigantic ape, inhabiting Western Africa, is described under the name of Gorilla.

Order 12. BIMANA.—The order *Bimana*, concluding at once the class *Mammalia* and the consideration of the Animal Series, is represented solely by Man (*Homo*). As distinguished from lower forms, and particularly from the *Anthropoid* Apes, Man's special characteristics may be conveniently considered under the two heads of his morphological and structural features, and his psychological characteristics.

Thus, regarding the general conformation of the body, we find the erect posture truly peculiar to Man; the structure of the plantigrade foot, and muscular arrangement of the limbs and trunk, exhibiting an adaptation to this posture. The arms are, further, shorter than the legs; the former members not assisting progression in any way. The thumb, or "pollex," is perfectly opposable to the other digits of the hand;

but the "hallux," or great toe, is inopposable, the feet being thus totally unfitted for prehensile purposes.

The body-covering in Man does not exhibit the same perfection of development that is witnessed in most other Mammals; the body being sparingly covered with hair. The teeth exhibit a characteristic arrangement, in that they form in both jaws a continuous series, uninterrupted by a "diastema" or interval (Fig. 129, C). The dental formula has already been given.

The relative size and superior organisation of the brain form the only remaining points of interest which may be noticed in the present instance. Thus the cerebral hemispheres are more largely developed as compared with the cerebellum; both portions of the brain, however, bearing marks of increased specialisa-

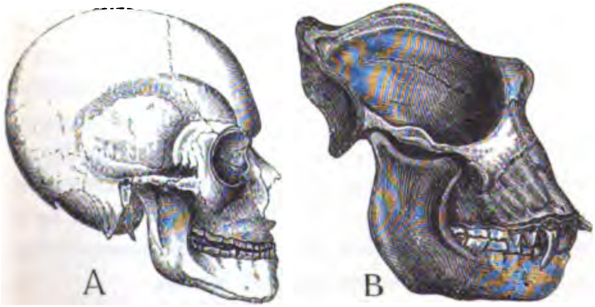


Fig. 150. Quadrumana and Bimana.
A, Skull of Adult European.
B, Skull of Gorilla (*Troglodytes Gorilla*).

tion to that observed in other Mammals. The convolutions of the brain, so faintly marked in the *Implacentalia*, and even in some of the higher *Mammalia*, are now seen to be distinctly developed, and to exhibit a characteristic complexity and intricacy of structure. In accordance with, and in relation to, this development of the chief nervous centres, we find the cranial portion of the skull predominating in size over the facial elements (Fig. 150, A); this feature forming a contrast to the similar conformation in the skulls of the lower *Mammalia* generally, or even in the skulls of the higher Apes (Fig. 150, B).

Turning from these structural characteristics, we are prepared to find the psychological differences between Man and the lower animals equally and as distinctly marked.

Amongst these superior and characteristic mental endowments may be enumerated the faculty of language and power of articulating sounds; whilst the moral sense of right and wrong, with the other and concomitant attributes of reason and intellect, separates Man by a wide gulf from all other living forms, and preserves his individuality for ever certain and distinct.

The palæontological relations of Man have formed subject-matter for much investigation and discussion. The chief evidences of Man's first appearance in Western Europe at least, consist in the rude implements of stone and flint used by the primitive inhabitants of that continent, and which are found in the deposits of the Post-Tertiary or Quaternary system. These sculptured flints, affording certain and positive evidence of Man's presence, have, in the earlier deposits of the system, been found associated with the remains of various extinct *Mammalia*, chief among which may be mentioned the Cave Bears and Hyænas, and also the Mammoth, with which man, in all probability, was thus an early contemporary.

Classification of Vertebrata.

Sub-Kingdom Vertebrata.

Class I. Pisces.	Order 1. *Pharyngobranchii.* Ex. Amphioxus.
	Order 2. *Marsipobranchii.* Ex. Petromyzon.
	Order 3. *Elasmobranchii.* Ex. Carcharias.
	Order 4. *Ganoidei.* Ex. Polypterus.
	Order 5. *Teleostei.* Ex. Salmo.
	Order 6. *Dipnoi.* Ex. Lepidosiren.
Class II. Amphibia.	Order 1. *Ophiomorpha.* Ex. Cæcilia.
	Order 2. *Urodela.* Ex. Triton.
	Order 3. *Anoura.* Ex. Rana.
	Order 4. *Labyrinthodontia.* Ex. Labyrinthodon.
Class III. Reptilia.	Order 1. *Chelonia.* Ex. Testudo.
	Order 2. *Ophidia.* Ex. Boa.
	Order 3. *Lacertilia.* Ex. Lacerta.
	Order 4. *Crocodilia.* Ex. Crocodilus.
Class IV. Aves.	Order 1. *Natatores.* Ex. Anas.
	Order 2. *Grallatores.* Ex. Ardea.
	Order 3. *Cursores.* Ex. Struthio.
	Order 4. *Rasores.* Ex. Gallus.
	Order 5. *Scansores.* Ex. Psittacus.
	Order 6. *Insessores:*
	Sub-order (*a*). *Dentirostres.* Ex. Turdus.
	Sub-order (*b*). *Conirostres.* Ex. Corvus.
	Sub-order (*c*). *Tenuirostres.* Ex. Trochilus.
	Sub-order (*d*). *Fissirostres.* Ex. Hirundo.
	Order 7. *Raptores.* Ex. Falco.
	Order 8. *Saururæ.* Ex. Archæopteryx.

- Class V. MAMMALIA.
  - Sub-class (A). IMPLACENTALIA.
    - Order 1. *Monotremata* (*Ornithodelphia*). Ex. Ornithorhynchus.
    - Order 2. *Marsupialia* (*Didelphia*). Ex. Macropus.
  - Sub-class (B). PLACENTALIA (*Monodelphia*).
    - Order 3. *Edentata*. Ex. Bradypus.
    - Order 4. *Sirenia*. Ex. Manatus.
    - Order 5. *Cetacea*. Ex. Balæna.
    - Order 6. *Ungulata* :
      - Sub-order (*a*). *Artiodactyla*. Ex. Ovis.
      - Sub-order (*b*). *Perissodactyla*. Ex. Tapirus.
      - Sub-order (*c*). *Proboscidea*. Ex. Elephas.
    - Order 7. *Carnivora*. Ex. Leo.
    - Order 8. *Rodentia*. Ex. Castor.
    - Order 9. *Insectivora*. Ex. Talpa.
    - Order 10. *Cheiroptera*. Ex. Pteropus.
    - Order 11. *Quadrumana*. Ex. Simia.
    - Order 12. *Bimana*. Ex. Homo.

GLOSSARY.

L, *Latin derivatives.* G, *Greek derivatives.*

Abdomen. (L. *abdo*, I conceal.) The posterior and larger cavity of the body in *Mammals*, and the third and terminal series of segments in the body of the higher *Annulosa*.

Abductor. (L. *ab*, from ; *duco*, I lead.) Applied to those muscles of certain *Molluscs*, the function of which is to open the shell by separating the valves.

Aberrant. (L. *aberro*, I wander from.) Departing or deviating from an ordinary or regular type.

Abomasum. The fourth sac or compartment of the compound stomach of *Ruminantia*.

Abranchiate. (G. *a*, without ; *bragchia*, gills.) Devoid of gills.

Acalephæ. (G. *akalephe*, a nettle.) A name sometimes applied to the *Medusiform Hydrozoa*, in allusion to their urticating or stinging properties.

Acanthocephala. (G. *acantha*, a thorn ; *kephale*, head.) A group of parasitic worms, having the head armed with spines or hooks.

Acarus. (G. *akari*, a mite.) A genus of *Arachnidans*, represented by the domestic mite and other forms.

Acephalous. (G. *a*, without ; *kephale*, head.) Destitute of a distinct head.

Acetabula. (L. *acetabulum*, a shallow cup.) A term applied to the suckers with which the arms of most *Cephalopoda* are provided.

Acetabulum. The socket of the hip-joint in *Vertebrata*.

Acrita. (G. *akritos*, confused.) A term used synonymously with *Protozoa*.

Actinia. (G. *aktis*, a ray.) A genus of *Cœlenterate* animals, of which the *Actinia* or Sea-anemone is the type.

Actinosoma. (G. *aktis*, and *soma*, body.) The entire body of an *Actinozoön*, whether of simple or compound structure.

Actinozoa. (G. *aktis*, and *zoon*, an animal.) A class of *Cœlenterate* animals represented by the *Actinia* or Sea-anemone.

Adductor. (L. *ad*, towards ; *duco*, I lead.) Applied to those muscles in *Lamellibranchiate* and other Molluscs, the function of which is to close the shell by approximating the valves.

Allantois. (G. *allas*, a sausage.) One of the fœtal or embryonic membranes of the higher *Vertebrata.*

Alternation of Generations. A form of the generative process observed in Invertebrata, in which the young do not resemble the parent but the grand-parent.

Alula. (L. diminutive of *ala*, a wing.) A little wing; applied to the small pinion borne by the thumb digit in Birds.

Alveolus. (L. *alvus*, belly.) A hollow cavity; but more particularly applied to the sockets in which the teeth are lodged.

Ambulacra. (L. *ambulacrum*, a garden walk.) The perforated spaces in the shell of the *Echini* or Sea-urchin. The tubular feet of *Echinozoa.*

Ametabolic. (G. *a*, without, and *metabole*, change.) Insecta which do not undergo any metamorphosis, and which do not possess wings in the perfect state.

Amnion. (G. *amnos*, a lamb.) One of the fœtal or embryonic membranes of the higher Vertebrata.

Amœba. (G. *amoibe*, a change.) A genus of *Rhizopoda*, so named from the changes of form its body undergoes.

Amorphous. (G. *a*, without, and *morphe*, form.) Devoid of regular form.

Amphibia. (G. *amphi*, both; *bios*, life.) Forms suited for existence on land and in water. Applied to a class of Vertebrates which possess gills in the young state; these organs being in the typical members of the class co-existent with lungs in the adult.

Amphicœlous. (G. *amphi*, both; *koilos*, hollow.) Applied to those vertebræ, the bodies of which are bi-concave or hollow at each end.

Amphioxus. (G. *amphi*, both; *oxus*, sharp.) The technical name of the *Lancelet*, a Fish, the sole example of the *Pharyngobranchii*, the body of which tapers at each extremity.

Amphipoda. (G. *amphi*, and *pous*, foot.) An order of Crustacea, in which the feet are used both for walking and swimming.

Analogy. (G. *analogia*, proportion.) The relation between parts which agree in function.

Anarthropoda. (G. *a*, without; *arthron*, a joint; *pous*, a foot.) One of the primary sections of the Annulosa, in which there are no jointed locomotive appendages.

Anchylosis. (G. *ankulos*, crooked.) The coalescence or union of two bones by ossification, so that all movement between them is prevented.

Annelida. A class of *Annulosa*, represented by the various kind of Worms.

Annulated. (L. *annulus*, a ring.) Composed of rings.

ANNULOIDA. (L. *annulus*, a ring, and G. *eidos*, form.) A term used synonymously with *Echinozoa*.

ANNULOSA. (L. *annulus*.) A sub-kingdom of animals, comprising the Worms, Insects, Spiders, and Crustaceans, in which the bodies are composed of rings or segments.

ANOMOURA. (G. *anomos*, irregular; *oura*, tail.) A group of *Decapodous Crustaceans*, represented by the Hermit Crab.

ANOPLOTHERIUM. (G. *a*, without; *oplon*, a weapon.) An extinct genus of *Mammals* unprovided with horns.

ANOPLURA. (G. *anoplos*, unarmed; *oura*, tail.) An order of Insects represented by Lice.

ANOURA. (G. *a*, without, and *oura*.) An order of *Amphibia* represented by the *Frogs*, in which the adult is destitute of a tail.

ANTENNÆ. (L. *antenna*, the yard of a ship.) The head or "cephalic" appendages of *Insects* and *Crustacea*, which are supposed to subserve the sense of touch.

ANTENNULES. The second and smaller pair of antennæ in *Crustaceans*.

ANTHROPOID. (G. *anthropos*, a man; *eidos*, form.) A term applied to the highest Apes, in reference to their resemblance to the human form.

ANTIBRACHIUM. (G. *anti*, in front of; *brachion*, the arm.) The forearm of higher *Vertebrata*.

ANTLIA. (L. *antlia*, a pump.) The spiral proboscis or trunk found in Butterflies and allied forms, by means of which they suck up the juices of flowers.

ANUS. (L. *anus*, the vent.) The vent or termination of the alimentary or digestive tract.

AORTA. (G. *aorte*, the wind-pipe.) Used in modern anatomy, to indicate the main systemic vessel or artery which arises from the left ventricle of the heart.

APHANIPTERA. (G. *aphanos*, hidden; *pteron*, a wing.) An order of *Insecta* in which the wings are rudimentary; represented by the Fleas.

APLACENTALIA. (G. *a*, without; L. *placenta*, a cake.) A group of the *Mammalia* represented by the Kangaroos, in which no vascular connection exists between the mother and the young animal before birth. (**IMPLACENTALIA.**)

APODA. (G. *a*, without; *poda*, feet.) A term applied to those forms destitute of locomotive organs, or which want the pelvic limbs or their homologues.

APTERA. (G. *a*, without; *pteron*, a wing.) A section of *Insecta*, distinguished by the absence of wings in the perfect insects.

APTERYX. (G. *a*, without; *pterux*, a wing.) The *Apteryx* or Wingless bird of New Zealand, classified with the *Cursores*.

ARACHNIDA. (G. *arachne*, a spider.) A Class of the *Annulosa*, including the Spiders, Scorpions, and allied forms.

ARANEINA. (L. *aranea*, a Spider.) An order of the class *Arachnida*, represented by Spiders.

ARCHÆOPTERYX. (G. *archaios*, ancient; *pterux*, a wing.) An extinct genus of Birds, forming the sole example of the order *Saururæ*.

ARCHENCEPHALA. (G. *archo*, I rule; *egkephalos*, brain.) The fourth and highest section of the *Mammalia*, according to Owen, which comprises Man only.

ARCTISCA. (G. *arktos*, a Bear.) An order of *Arachnida*, represented by the animalcules familiarly known as "Water Bears."

ARTHROGASTRA. (G. *arthron*, a joint; *gaster*, belly.) An order of *Arachnida*, with distinctly jointed abdomens, represented by the Scorpions.

ARTHROPODA. (G. *arthron*, and *poda*, feet.) One of the primary sections of the Annulosa, including those classes which possess jointed limbs.

ARTICULATA. (L. *articulus*, a little joint.) A term used synonymously with *Annulosa*.

ARTIODACTYLA. (G. *artios*, even; *daktulos*, a finger or toe.) An order of *Mammalia* with the toes of the feet in an even (two or four) number.

ASCARIS. (G. *askaris*, a mawworm.) The *Ascaris* or Round Worm, a member of the class *Scolecida*.

ASCIDIA. (G. *askos*, a bottle.) The technical name of the "Sea Squirts," included in the class *Tunicata*.

ASEXUAL. A term applied to forms of the reproductive process, in which the sexual elements do not take part. Exemplified among the *Hydrozoa* and *Mollusca* by the process of "gemmation" or "budding."

ASIPHONIDA. (G. *a*, without; *siphon*, a tube.) A division of the *Lamellibranchiate Molluscs*, which do not possess respiratory tubes or siphons.

ASSIMILATION. The process by which living bodies incorporate matter external to themselves, and convert it into their own substance—as in digestion and absorption.

ASTEROIDEA. (G. *aster*, a star; *eidos*, form.) An order of the class *Echinodermata*, including the Star-fishes.

ASTOMATOUS. (G. *a*, without; *stoma*, a mouth.) A term applied to those *Protozoa* which do not possess a distinct mouth.

ASTRAGALUS. (G. *astragalos*, a huckle bone.) The bone of the tarsus or instep, which articulates with the tibia.

ATLAS. (G. *Atlas*, the god who supports the earth.) The vertebra which articulates with the skull.

ATOLL. The Polynesian name for the perfect form of coral islands

Atrium. (L. *atrium*, an entrance hall.) The cloacal chamber of *Tunicate Molluscs.*

Auricle. (L. *auricula*, a little ear.) A cavity of the heart of the higher animals generally, the function of which is to proper blood into the ventricle.

Autophagi. (G. *autos*, self; *phago*, I eat.) A term applied to those Birds in which the young are immediately after birth comparatively independent of the parents' care.

Aves. (L. *avis*, a Bird.) A class of *Vertebrate* animals of oviparous habits, warm-blooded circulation, and body covered by peculiar skin-appendages termed "feathers."

Avicularium. (L. *avicula*, a little Bird.) A term applied to peculiar appendages resembling the heads of Birds, found parasitic on *Polyzoa.* The name, "Birds'-head processes" is used synonymously with *Avicularia.*

Axilla. (L. *axilla.*) The arm-pit.

Axis. (G. *axon*, a pivet.) The second cervical or neck vertebra, upon which the skull and first vertebra or "atlas" usually rotate.

Azygos. (G. *a*, without; *zugos*, a yoke.) An organ or appendage which, being situated in the middle line, has no fellow.

Bacterium. (G. *bakterion*, a staff.) A minute filamentous organism, found in infusions of organic matter after exposure to the atmosphere.

Baculite. (L. *baculus*, a staff.) An extinct chambered shell of straightened form, belonging to the *Cephalopodous Mollusca.*

Balanus. (G. *balanos*, an acorn.) A family of *Crustaceans*, included in the order *Cirripedia*, and commonly known as "Acorn shells."

Baleen. (L. *balæna*, a Whale.) The horny plates depending from the palate of the true Whales, and popularly known as "whalebone."

Batides. (G. *batos*, a bramble.) A division of the order *Elasmobranchii*, including the Skates and Rays.

Batrachia. (G. *batrachos*, a Frog.) A term used by Cuvier to indicate the class of *Vertebrates* now known as *Amphibia;* and sometimes applied to the Frogs and Toads, as forming an order of the *Amphibia.*

Belemnite. (G. *belemnon*, a dart.) An extinct genus of *Cephalopodous Mollusca*, allied to the existing *Sepia*, and provided with an elongated conical internal shell.

Bifid. Cleft in two, forked.

Bilateral. Having two symmetrical or equal sides.

Bimana. (L. *bis*, two; *manus*, a hand.) An order of *Mammalia*, represented solely by Man.

BIOLOGY. (G. *bios*, life; *logos*, a discourse.) The science of living beings; comprehending the two divisions of Botany and Zoology.

BIOPLASM. (G. *bios; plasso*, I form or mould.) Primordial matter, or "basis," of life. See PROTOPLASM.

BIVALVE. (L. *bis*, two; *valvæ*, folding doors.) A term applied to a shell which consists of two halves or valves.

BLASTODERM. (G. *blastos*, a sprout; and *derma*, skin.) The superficial skin or surface of the embryo in its earliest condition.

BLASTOIDEA. (G. *blastos; eidos*, appearance). An extinct order of *Echinodermata*.

BOTRYLLI. (G. *botrus*, a bunch of grapes). A group of compound *Tunicate Molluscs*, so called in reference to their berry-like appearance.

BRACHIOPODA. (G. *brachion*, the arm; *poda*, feet.) A class of *Molluscoida*, so named from the possession of two elongated arms springing from the sides of the mouth.

BRACHIUM. (G. *brachion*.) The upper arm of Vertebrates.

BRACHYURA. (G. *brachus*, short; *oura*, tail.) A section of *Decapodous Crustaceans*, in which the tail is abortive or rudimentary. The various kinds of Crabs exemplify this group.

BRADYPUS. (G. *bradus*, slow; *pous*, foot.) A genus of the order *Edentata*, represented by the Sloths.

BRANCHIA. (G. *bragchia*, gills.) A gill or respiratory organ for breathing the air contained in water.

BRANCHIATE. Possessing branchiæ or gills.

BRANCHIFERA. (G. *bragchia*, and *phero;* I carry.) A group of *Gasteropodous Molluscs*, in which the respiration is carried on by means of distinct gills.

BRANCHIOPODA. (G. *bragchia*, and *poda*, feet.) An order of *Crustacea*, in which the gills are borne by the feet.

BREVILINGUIA. (L. *brevis*, short; *lingua*, a tongue.) A group of the *Lacertilia* or Lizards, in which the tongue is short and non-protrusible.

BREVIPENNATÆ. (L. *brevis; penna*, a wing.) A family of *Natatorial* Birds, in which the wings are small or rudimentary.

BRONCHI. (G. *brogchos*, the windpipe.) The subdivisions of the trachea or windpipe in the lung.

BRUTA. (L. *brutus*, heavy.) Synonymous with *Edentata*.

BRYOZOA. (G. *bruon*, moss; *zoön*, animal). A term occasionally employed to designate the *Polyzoa*.

BUCCAL. (L. *bucca*, the mouth.) Belonging to the mouth

BYSSUS. (G. *bussos*, fine linen.) The silky filaments produced by the foot of certain *Molluscs*, such as the Common Mussel.

Caducous. (L. *caducus*, falling off.) Applied to parts or organs falling off, or being shed during life.

Caducibranchiate. (L. *caducus*; G. *bragchia*, gills.) A group of *Amphibia*, in which the gills are shed before adult life is attained.

Cæcum. (L. *cæcus*, blind.) A tube terminating in a blind or closed extremity. Applied to the first portion of the large intestine in *Mammals*.

Calcaneum. (L. *calx*, the heel.) The bone of the tarsus forming the heel.

Calcar. (L. *calcar*, a spur.) Applied to the spurs of *Rasorial* Birds.

Calcareous. (L. *calx*, lime.) Composed of lime.

Calycophoridæ. (G. *kalus*, a cup; *phero*, I carry.) An order of *Hydrozoa*, possessing cup-shaped swimming organs, known as "nectocalyces."

Calyx. (L. *calyx*, a cup.) A cup-shaped disc or body.

Campanularia. (L. *campanula*, a bell.) A genus of *Hydroid* Polypes.

Canine. (L. *canis*, a dog.) Applied to the eye or dog teeth of *Mammals*, specially developed in *Carnivora* or flesh-eating animals.

Carapace. A shield or covering. Applied to the dorsal shell of *Crustacea*, and to the upper shield of *Chelonian* Reptiles.

Cardia. (L. *cardo*, the hinge of a door.) The upper or œsophageal opening of the stomach.

Carinatæ. (L. *carina*, a keel.) A division of Birds which possess a sternal ridge or keel.

Carnivora. (L. *caro*, flesh; *voro*, I devour.) An order of *Mammalia*.

Carpophaga. (G. *karpos*, fruit; *phago*, I eat.) A group of *Marsupialia*, feeding on vegetable matters.

Carpus. (G. *karpos*, the wrist.) The bones between the forearm and hand, familiarly known as the wrist.

Catarhina. (G. *kata*, downwards; *rhines*, nostrils.) A group of the *Quadrumana* or Monkeys.

Caudal. (L. *cauda*, the tail.) Belonging to the tail.

Cavicornia. (L. *cavus*, hollow; *cornu*, horn.) A group of *Ruminant* quadrupeds.

Cell. (L. *cella*, a small room.) Applied to any small cavity, but commonly used to indicate a microscopical element of form, consisting of a rounded body composed of a cell-wall, cell-contents, and a contained solid particle, termed the nucleus.

Centrum. (G. *kentron*, the prick made by one leg of a pair of compasses.) The solid central portion or body of a vertebra.

Cephalic. (G. *kephale*, the head.) Belonging to the head.

CEPHALOPHORA. (G. *kephale; phero*, I carry.) A section of *Mollusca*, possessing a distinct head.

CEPHALOPODA. (G. *kephale; poda*, feet.) A class of *Mollusca* possessing a distinct head surrounded by a circle of arms or tentacles.

CEPHALOTHORAX. (G. *kephale; thorax*, chest.) The united head and thorax of *Annulose* animals.

CERCARIÆ. (G. *kerkos*, tail.) An aquatic Worm, representing a stage in a development of the *Distomidæ* or "Flukes."

CERVICAL. (L. *cervix*, the neck.) Belonging to the region of the neck.

CESTOIDEA. (G. *kestos*, a girdle.) A term occasionally employed to designate the *Tæniada* or Tape-worms.

CESTRAPHORI. (G. *kestra*, a weapon; *phero*, I carry.) A group of *Elasmobranchii*, represented solely by the Port Jackson Shark.

CETACEA. (G. *ketos*, a whale.) An order of *Mammalia*, including the Whales.

CHÆTOGNATHA. (G. *chaite*, hair; *gnathos*, the jaw.) A group of *Annulosa*, represented by the aberrant form *Sagitta*.

CHEIROPTERA. (G. *cheir*, the hand; *pteron*, wing.) An order of *Mammals*, represented by the Bats.

CHELÆ. (G. *chele*, a claw.) Modified limbs, forming pincer-like claws, as in Crabs and their allies.

CHELICERÆ. (G. *chele; keras*, horn.) The modified antennæ of Scorpions.

CHELONIA. (G. *chelone*, a Tortoise.) An order of *Reptiles*, represented by the Turtles and Tortoises.

CHILOGNATHA. (G. *cheilos*, lip; *gnathos*, jaw.) An order of *Myriapoda*, including the *Millipedes*.

CHILOPODA. (G. *cheilos; poda*, feet.) An order of *Myriapoda*, including *Centipedes*.

CHIMÆRA. (G. *chimaira*, a monster like a Goat.) A genus of *Elasmobranchii*, familiarly known as the "King of the Herrings."

CHITIN. (G. *chiton*, a tunic.) The peculiar chemical principle allied to horn, of which the hard parts of many *Annulose* animals are composed.

CHLOROPHYLL. (G. *chloros*, green; *phullon*, a leaf.) The green colouring matter of plants.

CHORION. (G. *chorion*, a skin.) The vascular membrane which surrounds the embryo of *Vertebrates*.

CHROMATOPHORA. (G. *chroma*, colour; *phero*, I carry.) The cells containing pigment or colouring matter found in the skin of *Cephalopoda*.

CHRYSALIS. (G. *chrusos*, gold.) The pupa of *Lepidopterous* Insects.

CHYLAQUEOUS FLUID. A fluid consisting of the chyle or product of digestion, and water, found in the perivisceral spaces or body-cavities of the *Echinozoa* and *Annulosa*.

CHYLE. (G. *chulos*, juice.) The nutrient fluid or result of the final action of the digestive juices.

CHYME. (G. *chumos*, juice.) The acid fluid resulting from the action of the gastric juice in the stomach.

CILIA. (L. *cilium*, an eyelash.) Microscopic filaments, exhibiting rhythmical movements, found generally distributed over various membranes in the organic series.

CIRRI. (L. *cirrus*, a curl.) Filamentous appendages, found very generally distributed throughout the *Annulosa* and *Mollusca*.

CIRRIPEDIA. (L. *cirrus; pes*, a foot.) An order of *Crustacea*, possessing feet in the form of cirrous filaments.

CIRROSTOMI. (L. *cirrus;* G. *stoma*, mouth.) A term applied to the *Pharyngobranchii*.

CLAVICLE. (L. *clavicula*, a little key.) The clavicle or collar-bone, one of the bones of the shoulder girdle in *Vertebrata*.

CLOACA. (L. *cloaca*, a sink.) The common cavity into which the terminal portion of the intestine, and the efferent ducts of the urinary and generative organs open, in some *Invertebrates;* in the *Sauropsida;* and in certain of the lower *Mammals*.

CNIDÆ. (G. *knide*, a nettle.) The minute vesicles or "thread cells," peculiar to *Cœlenterate* animals, by means of which they are enabled to produce stinging sensations.

COCCOLITHS. (G. *kokkos*, a berry; and *lithos*, a stone.) Minute bodies of spherical shape existing as free organisms, or attached to the surface of *Coccospheres*.

COCCOSPHERES. (G. *kokkos; sphaira*, a sphere.) Minute masses of protoplasm, usually enclosed in a calcareous capsule, found forming, with other organisms of a similarly low (*Protozoic*) type of structure, vast fields of life in the bed of the ocean.

COCCYX. (G. *kokkux*, a cuckoo.) The terminal portion of the vertebral column in Man.

COCOON. (French *cocon*, a cocoon, from Latin, *concha*, a shell.) The pupa case, investing the body of many insects during the pupa or chrysalis stage of their metamorphosis.

CŒLENTERATA. (G. *koilos*, hollow; *enteron*, the bowel.) A sub-kingdom of animals, including the classes *Hydrozoa* and *Actinozoa*. The term is derived from the fact of the digestive sac and body cavity being in free communication with each other.

CŒNENCHYMA. (G. *koinos*, common; *enchuma*, tissue.) The common tissue uniting together the polypes or zoöids of a compound organism. Example—the calcareous matter uniting the various corallites of a compound coral.

Cœnœcium. (G. *koinos; oikos*, house.) The connecting skin or integument uniting the "polypides" of the *Polyzoa.*

Cœnosarc. (G. *koinos; sarx*, flesh.) The connecting medium of the "hydrosoma," or entire organism, of a compound *Hydrozoön.*

Coleoptera. (G. *koleos*, a sheath; *pteron*, wing.) An order of *Insecta*, represented by the Beetles, in which the anterior wings are converted into "elytra" or sheaths for the posterior pair.

Colubrina. (L. *coluber*, a Snake.) A group of the order *Ophidia.*

Columella. (L. *columella*, a little pillar.) A term applied firstly to the central pillar or axis around which the whorls of a spiral shell are wound (*Gasteropoda*); and secondly, to the central axis of the coral structure in *Sclerodermic* "Corallites."

Commissural. (L. *committo*, I solder together.) Applied to the nerve fibres which unite "ganglia" or nerve masses together.

Concha. (L. *concha*, a shell.) The external ear.

Conchifera. (L. *concha; fero*, I carry.) Shell-bearers; applied to those *Molluscs* which possess bivalve shells (*Lamellibranchiata.*)

Condyle. (G. *kondulos*, a knuckle.) The articular surface by which two bones are articulated together; applied especially to the articular processes, by means of which the occipital bone of the skull articulates with the spinal column.

Conirostres. (L. *conus*, a cone; *rostrum*, a beak.) A sub-order of "perching" Birds, possessing conical beaks.

Coracoid. (G. *korax*, a Crow; *eidos*, form.) Applied to the "coracoid bone," or second clavicle of *Vertebrata*, one of the bones entering into the composition of the pectoral arch.

Corallite. (G. *korallion*, coral.) The coral or hard calcareous structure secreted by a single *Actinozoön*, or the corallum secreted by a single zoöid of a compound polype.

Corallum. The hard structure secreted by the tissues of an *Actinozoön.*

Coriaceous. (L. *corium*, hide.) A texture of leathery consistence.

Corpus Callosum. (L. "the firm body.") The great commissure or band of nervous matter uniting the two hemispheres or halves of the true brain in *Mammals.*

Corpuscle. (L. *corpusculum*, a particle.) A minute rounded body or sphere. Usually applied to the solid particles found in the blood, "chyle," and other organic fluids.

Cortical Layer. (L. *cortex*, bark.) The second or inner skin, of firm sarcode, found in the *Infusoria*, and which encloses the inner fluid contents, or "chyme-mass."

Cranium. (G. *kranion*, the skull.) The skull or bony case, in which the brain of *Vertebrates* is enclosed.

Craspeda. (G. *kraspedon*, a fringe.) The cord-like, convoluted structures, attached to the faces of the mesenteries of the *Actiniæ* or "Sea-Anemones. They are richly supplied with "cnidæ" or "thread-cells," but their function is unknown.

Crepuscular. (L. *crepusculum*, dusk.) A term applied to certain Insects, Bats, and other forms, which appear at or during twilight.

Crinoidea. (G. *krinon*, a lily; *eidos*, form.) An order of *Echinodermata*, including forms which exist during the whole or a part of their existence as stalked organisms. The order is abundantly exemplified by fossil forms, resembling lilies, and termed "Encrinites," or "Stone-lilies."

Crocodilia. (G. *krokodeilos*, a crocodile.) An order of *Reptilia*, including the Crocodiles.

Crop. A dilatation of the œsophagus, serving as a food-receptacle, found in Insects and Crustacea, in some Mollusca, but more typically in Birds (*Ingluvies*).

Crustacea. (L. *crusta*, a shell.) A class of *Annulosa*, including Lobsters and Crabs, distinguished by the possession of a hard "shell" or "crust."

Ctenocyst. (G. *kteis*, a comb; *kustis*, a sac or cyst.) A small cyst or sac, containing calcareous particles (*otoliths*), found in the *Ctenophora*, and supposed to subserve the auditory or hearing sense.

Ctenoid. (G. *kteis*; *eidos*, form.) Those scales in Fishes which exhibit a comb-like structure on their posterior margins. Ex. Perch.

Ctenophora. (G. *kteis*; *phero*, I bear.) An order of *Actinozoa*, including forms which swim by aid of bands of cilia, arranged in comb-like plates, termed "ctenophores."

Cursores. (L. *curro*, I run.) An order of Birds, in which the power of flight is modified, and the legs formed for terrestrial progression. Ex. Ostrich.

Cuspidate. (L. *cuspa*, a point or cusp.) Applied to teeth furnished with small points or "cusps."

Cuticle. (L. *cuticula*, diminutive of *cutis*, skin.) The outer layer of the integument; otherwise known as the "epidermis," or "scarf-skin." The outer layer of the body in the *Infusoria*.

Cutis. (L. *cutis*.) The term applied to the inner layer, true skin, or "cutis vera," "corium," or "derma," as distinguished from the "cuticle" or "epidermis."

Cyclobranchiata. (G. *kuklos*, a ring; *bragchia*, gills.) A family of *Gasteropoda*, represented by the Limpets, in which the gills are arranged in a circle round the body.

Cycloid. (G. *kuklos*: *eidos*, form.) Those scales in Fishes, which are of simple rounded form, with an unindented margin. Ex. Herring.

CYCLOSTOMI. (G. *kuklos; stoma*, mouth.) A term used synonymously with *Marsipobranchii*, in allusion to the rounded sucker-like mouths of the fishes (Lamprey, etc.) included in that order.

CYST. (G. *kustis*, a sac or bladder.) A sac or vesicle.

CYSTIC WORMS. The old term applied to the "Scolices" or "Resting-larvæ," representing the transitionary stage in the development of the *Tæniada* or "Tape-worms."

CYSTOIDEA. (G. *kustis;* and *eidos*, form.) An extinct order of *Echinodermata*.

DECAPODA. (G. *deka*, ten; *poda*, feet.) An order of *Crustacea*, in which ten walking feet are present: Ex. Lobsters. A section of the *Dibranchiate Cephalopoda*, possessing ten arms or feet.

DECIDUA. (L. *de*, from; *cado*, I fall.) The modified mucous or lining membrane of the pregnant uterus, when it falls off after the birth of the contained embryo.

DECIDUOUS. (L. *decido*, I fall off.) Parts which are shed or fall off during the life of the animal.

DEMODEX. (G. *demos*, fat; *dex*, a boring-worm.) The worm-like minute parasite which inhabits the follicles of the human skin.

DENTIROSTRES. (L. *dens*, a tooth; *rostrum*, a beak.) A sub-order of "Perching" Birds, in which the beak has its upper mandible notched or serrated.

DENTITION. (L. *dens*, a tooth.) The arrangement of the teeth in a particular animal or group.

DERMA. (See CUTIS.)

DERMAL. (G. *derma*, skin.) Belonging to the skin.

DEXTRAL. (L. *dextra*, the right hand.) Applied to those *Gasteropodous* shells, in which the whorls of the shell are wound to the right-hand side.

DIAPHRAGM. (G. *diaphragma*, a partition.) The muscular partition which, in *Mammals*, separates the thoracic from the abdominal cavity.

DIASTEMA. (G. *dia*, apart; *histemi*, to place.) An interval; specially applied to the intervals or spaces between the teeth in *Mammals*.

DIASTOLE. (G. *diastello*, I separate.) Applied to the expansion of the cavities of the heart, in contradistinction to its contraction or "systole."

DIATOMACEÆ. (G. *diatemno*, to cut through.) The siliceous or flinty coverings of minute vegetable organisms of a low type of organisation.

DIBRANCHIATA. (G. *dis*, twice; *bragchia*, gills.) The order of Cuttlefishes (*Cephalopoda*), having two gills.

DICYNODONTIA. (G. *dis*, twice; *kuon*, dog; *odous*, a tooth.) An extinct order of *Reptilia*, possessing two canine or dog-like teeth.

DIDELPHIA. (G. *dis*, twice; *delphus*, womb.) The sub-class of *Marsupial* Mammals, possessing a double uterine cavity.

DIFFERENTIATION. (*See* SPECIALISATION.)

DIGIT. (L. *digitus*, a finger.) A finger or toe.

DIGITIGRADA. (L. *digitus; gradior*, I walk.) Applied to those *Carnivorous Mammalia* which walk on the phalanges of their fore and hind feet.

DIMYARIA. (G. *dis*, twice; *muon*, a muscle.) A division of the class *Lamellibranchiata*, comprising those forms, the shells of which are closed by two adductor muscles.

DINOSAURIA. (G. *deinos*, terrible; *saura*, a Lizard.) An extinct order of Reptilia.

DIPHYODONT. (G. *dis*, twice; *phuo*, I produce; *odous*, tooth.) Applied to those *Mammals* in which two sets of teeth are produced during the lifetime of the animal.

DIPNOI. (G. *dis*, twice, or double; *pnoe*, breath.) The order of Fishes of which the *Lepidosiren* is the sole representative. Applied to the order on account of this form breathing both by gills and lungs (*Protopteri*).

DIPTERA. (G. *dis; pteron*, wing.) An order of *Insecta*, including the Flies, which possess only two wings.

DISCOPHORA. (G. *diskos*, a quoit; *phero*, I bear.) An order of *Annelida*, sometimes known as *Suctoria*, or *Hirudinea*, represented by the Leeches, and so named from the possession of two locomotive discs.

DISSEPIMENTS. (L. *dissepio*, I partition off.) Transverse partitions, borne by the vertical septa of *Sclerodermic* "Corallites."

DISTAL. Applied to the free extremity of the "hydrosoma" of a hydrozoon, in contradistinction to the attached extremity, or "proximal" end.

DISTOMA. (G. *dis*, twice; *stoma*, mouth.) A genus of parasitic worms, popularly known as "Liver-flukes," and which possess two oral openings or "pores." (*See* CERCARIÆ.)

DIURNAL. (L. *dies*, day.) Applied to those animals which move abroad during the day.

DIVERTICULUM. (L. *diverticulum*, a bye-road.) Applied to a cæcal or blind tube, springing from the side of another tube.

DORSAL. (L. *dorsum*, back.) Belonging to the back, or "dorsal" region.

DORSIBRANCHIATA. (L. *dorsum;* G. *bragchia*, gills.) Having external gills attached to the back, as exemplified by certain *Annelida* and *Mollusca* (*Notobranchiata*).

DUODENUM. The first portion of the intestine, so called, because in the human subject it equals the breadth of twelve fingers.

ECDERON. (G. *ek*, out; *deros*, skin.) The outer of the two layers into which the ectoderm is divided, and which in the coral-bearing *Actinozoa* secretes the "corallum."

ECDYSIS. (G. *ekdusis*, a stripping off.) The moulting of the skin observed in the larvæ or caterpillars of certain insects.

ECHINOCOCCI. (G. *echinos*, a hedgehog; *kokkos*, a berry.) The cystic forms of the Tape-worm of the Dog (*Tænia echinococcus*), otherwise known as "Hydatids."

ECHINODERMATA. (G. *echinos; derma*, skin.) A class of *Echinozoa*, represented by the Sea-urchins (*Echini*) and Star Fishes; so named from the spiny character of the integument.

ECHINOIDEA. (G. *echinos; eidos*, form.) An order of *Echinodermata*.

ECHINORHYNCHUS. (G. *echinos; rhunchos*, beak.) A genus of *Nematelmia* or Round Worms.

ECTOCYST. (G. *ektos*, outside; *kustis*, a bladder.) The external layer of the cœnœcium of the *Polyzoa*.

ECTODERM. (G. *ektos; derma*, skin.) The external layer of the skin of Cœlenterata.

ECTOSARC. (G. *ektos; sarx*, flesh.) The outer layer of the protoplasm in the *Rhizopoda*.

EDENTATA. (L. *e*, without; *dens*, tooth.) An order of *Mammalia* in which the teeth are wholly or partially absent (*Bruta*).

EDENTULOUS. Toothless.

EDRIOPHTHALMIA. (G. *hedraios*, sitting; *ophthalmos*, eyes.) A division of *Crustacea*, in which the eyes are sessile, or unsupported on stalks.

ELASMOBRANCHII. (G. *elasma*, a thin plate; *bragchia*, gills.) An order of Fishes, including the Sharks and Rays.

ELYTRA. (G. *elutron*, a sheath.) The horny anterior pair of wings found in Beetles (*Coleoptera*), and which serve as sheaths or cases for the posterior pair.

EMBRYO. (G. *en*, in; *bruo*, I swell.) The earliest stage at which the future animal can be detected in the impregnated ovum or egg.

ENCEPHALON. (G. *egcephalos*, brain.) The nervous mass contained within the skull of *Vertebrata*, and familiarly known as the brain.

ENCEPHALOUS. (G. *en*, in; *kephale*, the head.) Applied to those *Mollusca* in which a distinct head is recognisable.

ENDERON. (G. *en; deros*, skin.) The inner layer of the outer skin or ectoderm of *Cœlenterata*.

ENDOCYST. (G. *endon*, within; *kustis*, a bag.) The inner layer or true skin of *Polyzoa*.

Endoderm. (G. *endon; derma*, skin.) The inner layer of the integument in *Cœlenterata*.

Endopodite. (G. *endon*, within; *pous*, foot.) The inner secondary joint or segment of the typical limb of *Crustacea*.

Endosarc. (G. *endon; sarx*, flesh.) The inner layer of protoplasm in *Rhizopoda*.

Endoskeleton. (G. *endon; skeletos*, dry.) The internal hard structures (bones) of *Vertebrata*, known collectively as the skeleton, and used for the attachment of muscles, and support of the soft parts; so called in contradistinction to hard developments of the skin, which are accordingly known as the "exoskeleton."

Endostyle. (G. *endon; stulos*, a pillar.) A fold of the lining membrane of the pharynx in Tunicate Molluscs (*Ascidia*).

Entomology. (G. *entoma; logos*, a discourse.) The division of Zoological science which treats of insects.

Entomophaga. (G. *entoma*, insects; *phago*, I eat.) A section of *Marsupial Mammals*, represented by the Opossums, which feed on insects.

Entomostraca. (G. *entoma; ostrakon*, a shell.) A division of *Crustacea*.

Entozoa. (G. *entos*, within; *zoön*, animal.) Animals which are parasitic within other animals. A term formerly applied to the *Scolecida*.

Eocene. (G. *eos*, dawn; *kainos*, new.) The lowest division of the Tertiary Rocks in which living species of animals are represented to a limited extent.

Epidermis. (G. *epi*, upon; *derma* the true skin.) The outer layer of the skin destitute of nerves or blood-vessels, and otherwise known as the cuticle or scarf-skin.

Epipodite. (G. *epi; pous*, foot.) A process borne by the protopodite of certain limbs in *Crustacea*. (*See* Scaphognathite.)

Epistome. (G. *epi; stoma*, the mouth.) A valve-like structure overhanging the mouth in certain *Polyzoa*.

Epitheca. (G. *epi; theke*, a sheath.) A continuous layer of coral structure, surrounding the "theca" or chamber-like receptacle in *Sclerodermic* Corals.

Epizoa. (G. *epi*, upon; *zoön*, animal.) Applied to certain lower *Crustaceans*, found parasitic on Fishes.

Equilateral. (L. *æquus*, equal; *latus*, a side.) Equal-sided. Applied to certain *Molluscan* shells, such as those of the *Brachiopoda*.

Equivalve. (L. *æquus; valvæ*, folding doors.) Applied to bivalve shells, the valves of which are of equal size.

Errantia. (L. *errare*, to wander.) An order of *Annelida*, the members of which possess considerable power of movement.

EURYPTERIDA. (G. *eurus*, broad; *pteron*, wing.) An extinct group of *Crustacea*.

EXOPODITE. (G. *exo*, outside; *pous*, a foot.) The outer secondary joint or segment of the typical limb of *Crustacea*.

EXOSKELETON. (G. *exo; skeletos*, dry.) The external skeleton, so called in contradistinction to the endoskeleton or internal framework, and which is formed by hard depositions in the integument or skin; whence it is also sometimes called the "dermo-skeleton."

FAUNA. (L. *Fauni*, the rural deities of the Romans.) A collective term for the animal life of a country, zone, or district.

FEMUR. The thigh-bone situated between the pelvis and bones of the leg.

FIBULA. (L. *fibula*, the pin of a brooch.) The external and lesser bone of the leg in the higher *Vertebrata*.

FILIFORM. (L. *filum*, a thread; *forma*, shape). Shaped or formed like a thread.

FIMBRIATED. (L. *fimbria*, a fringe.) Fringed.

FISSILINGUIA. (L. *findo*, I cleave; *lingua*, tongue.) A group of the *Lacertilia* or Lizards, with cleft tongues.

FISSION. (L. *fissus*, cleft.) The process of self-division or cleavage, a mode of reproduction seen in the lower forms of animal and plant life.

FISSIPAROUS. (L. *findo*, I cleave; *pario*, I bring forth.) Giving rise to new structures or individuals by fission.

FISSIROSTRES. (L. *fissus*, cleft; *rostrum*, beak.) A sub-order of *Perching* Birds, in which the beak is cleft far back on the head. Ex. Swallow.

FLAGELLUM. (L. *flagellum*, a whip.) The single lash-like appendage of certain *Infusorians*, termed accordingly *Flagellata*.

FLORA. (L. *Flora*, the goddess of flowers.) A collective term for the plant life of a country or district.

FOLLICLE. (L. *folliculus*, a little bag.) Minute secreting bags or sacs, which open upon mucous membranes.

FOOT-JAWS. Those locomotive appendages of *Crustacea*, which are modified to subserve the function of mastication.

FORAMINIFERA. (L. *foramen*, a hole; *fero*, I carry.) A group of *Rhizopoda* (*Protozoa*), the bodies of which are enclosed in hollow calcareous shells, through apertures in which, the protoplasm of which they are composed is protruded.

FRUGIVOROUS. (L. *frux*, fruit; *voro*, I devour.) Living upon fruits.

FURCULUM. (L. *furca*, a fork.) The V-shaped bone in Birds, formed by the united clavicles or collar bones; familiarly termed the "merrythought."

FUSIFORM. (L. *fusus*, a spindle; *forma*, shape.) Pointed at both ends; spindle-shaped.

GALEOPITHECUS. (G. *galen*, a weasel; *pithekos*, an ape.) A genus of animals allied to the *Insectivora*, and familiarly known as Flying Lemurs.

GALLINACEI. (L. *gallina*, a fowl.) A section of the order *Rasores*, represented by the Domestic fowl.

GANGLION. (G. *gagglion*, a swelling.) A mass of nervous matter, forming a centre of the nervous system, containing nerve cells, and receiving and giving out impressions.

GANOIDEI. (G. *ganos*, splendour.) An order of Fishes covered with ganoid scales, and represented in greater part by extinct forms.

GASTEROPODA. (G. *gaster*, belly; *pous*, foot.) A class of *Mollusca* possessing a ventral locomotive disc or foot.

GEMMA. (L. *gemma*, a bud.) The bud or individual produced by an animal organism, and which usually contains the essential elements of a new form.

GEMMATION. The process of asexual reproduction by budding.

GEMMIPAROUS. (L. *gemma; pario*, I produce.) Giving origin to new individuals or structures by means of budding.

GEMMULE. An encysted mass of sponge particles, from which new individuals are produced.

GEPHYREA. (G. *gephura*, a bridge.) A class of *Annulosa*, including the Spoon Worms.

GERM-CELL. The first nucleated cell that appears in the ovum after impregnation.

GERM-VESICLE. The nucleated cell, existing as the essential part of the unimpregnated ovum.

GLAND. (L. *glans*, an acorn.) A term applied to those organs which secrete from the blood certain fluids, which are elaborated by the glandular structures, and excreted from the gland, usually by a separate duct.

GONOBLASTIDIUM. (G. *gonos*, offspring; *blastidion*, a little bud.) The processes which bear the reproductive buds or "gonophores" in *Hydrozoa*.

GONOPHORE. (G. *gonos; phero*, I carry.) The generative buds or receptacles of the *Hydrozoa*.

GONOSOME. (G. *gonos; soma*, body.) Applied collectively to the generative zoöids of a *Hydrozoön*.

GRALLATORES. (L. *gralla*, a stilt.) An order of Birds.

GRANIVOROUS. (L. *granum*, a grain; *voro*, I devour.) Living upon grain or seeds.

GRAPTOLITE. (G. *grapho*, I write; *lithos*, stone.) An extinct order of *Hydrozoa*.

GREGARINA. (L. *gregarius*, occurring in a flock or herd.) A genus of *Protozoa*, representing the class *Gregarinida*.

GYMNOLÆMATA. (G. *gumnos*, naked; *laimos*, throat.) An order of *Polyzoa*, in which the mouth is unprotected by an "epistome."

GYMNOPHIONA. (G. *gumnos*; *ophis*, a snake.) An order of *Amphibia*.

GYMNOSOMATA. (G. *gumnos*; *soma*, the body.) An order of *Pteropoda*, in which the body is destitute of a shell.

HÆMAL. (G. *haima*, blood.) Relating to the blood-vascular or circulatory system.

HALLUX. (L. *hallex*, the great toe.) The innermost of the five normal digits of the *Vertebrate* foot.

HALTERES. (G. *halteres*, weights held in the hand in leaping.) The modified second pair of wings in *Dipterous* Insects, which exist as delicate filaments, and are supposed to be of use in balancing the animal.

HECTOCOTYLUS. (G. *hekaton*, a hundred, and *kotulos*, a cup.) The peculiar reproductive arm of male *Cephalopoda*, formerly described as a separate organism.

HEMIMETABOLA. (G. *hemi*, half; *metabole*, change.) A section of the *Insecta*, including those insects which undergo an incomplete metamorphosis.

HEMIPTERA. (G. *hemi*, and *pteron*, wing.) An order of Insects possessing the halves of the anterior wings of coriaceous or leathery consistence.

HERMAPHRODITE. (G. *Hermes*, Mercury; *Aphrodite*, Venus.) Applied to those animals, the sexes of which are contained in one and the same individual.

HETEROCERCAL. (G. *heteros*, diverse; *kerkos*, tail.) A term applied to the "caudal" or tail-fin of *Fishes*, when composed of two unequal halves or lobes.

HETEROGANGLIATA. (G. *heteros*; *gagglion*, a knot.) A term applied to the *Mollusca*, in allusion to the unsymmetrical disposition of the nervous system in that type of structure.

HETEROPHAGI. (G. *heteros*, other; *phago*, I eat.) A division of Birds in which the young are hatched in a comparatively immature condition.

HIRUDINEA. (L. *hirudo*, a Horse-leech.) An order of *Annelida*, represented by the Leeches.

HOLOCEPHALI. (G. *holos*, entire; *kephale*, head.) A sub-order of *Elasmobranchii* represented by the *Chimæra*.

HOLOMETABOLA. (G. *holos*; *metabole*, change.) A section of the *Insecta*, including those forms which undergo a complete metamorphosis.

HOLOSTOMATA. (G. *holos*; *stoma*, mouth.) A group of *Gastero-*

poda, in which the aperture of the shell is unindented or entire.

HOLOTHURIA. (G. *holothourion*, a Sea-cucumber.) A genus of *Echinodermata*, representing the order *Holothuroidea*, and familiarly known as "Sea-cucumbers and Trepangs."

HOMOCERCAL. (G. *homos*, similar; *kerkos*, tail.) Applied to the "caudal" fin of fishes when composed of two equal halves or lobes.

HOMOGANGLIATA. (G. *homos; gagglion*, a knot.) Applied to the *Annulosa*, in allusion to the symmetrical disposition of the nervous system in that sub-kingdom.

HOMOLOGY. (G. *homos; logos*, a discourse.) Applied to parts or organs constructed on the same fundamental type or plan. The relation between parts developed out of the same embryonic structures.

HUMERUS. The single bone composing the "brachium," or upper arm of the higher Vertebrata.

HYDATIDS. (*See* ECHINOCOCCI.)

HYDRIFORM. (G. *hudra*, a Water-serpent; L. *forma*, form.) Resembling the *Hydra*, or freshwater Polype, in form.

HYDRORHIZA. (G. *hudra; rhiza*, root.) The adherent basal portion or proximal and attached end of a Hydrozoön.

HYDROSOMA. (G. *hudra; soma*, body.) The entire organism, simple or compound, of a Hydrozoön.

HYDROTHECA. (G. *hudra; theke*, a sheath or case.) The chitinous or horny cases in which the polypites of certain *Hydrozoa* (*Sertularida*) are protected.

HYDROZOA. (G. *hudra; zoön*, animal.) A class of *Cœlenterata*, of which the *Hydra*, or "Common freshwater Polype," is the typical representative.

HYMENOPTERA. (G. *humen*, a membrane; *pteron*, wing.) An order of *Insecta* possessing four large membranous wings.

HYOID. (G. *U; eidos*, form.) The *os linguæ*, or "tongue-bone;" so named from its resemblance in man to the Greek letter U.

HYRACOIDEA. (G. *hurax*, a shrew; *eidos*, form.) An order of certain systems of *Mammalian* classification, including the single genus *Hyrax*, the "Coney" or Rabbit of Scripture.

ICHTHYODORULITE. (G. *ichthus*, fish; *dorus*, spear; *lithos*, stone.) The fossil fin-spines of Fishes, but principally those of the *Elasmobranchii*.

ICHTHYOMORPHA. (G. *ichthus; morphe*, form.) An order of *Amphibia*, including the Newts, so called in allusion to their Fish-like shape.

ICHTHYOPSIDA. (G. *ichthus; opsis*, appearance.) A province of the Vertebrata, including the classes *Pisces* and *Amphibia*.

ICHTHYOSAURIA. (G. *ichthus; saura*, a Lizard.) An extinct genus of *Reptilia*.

IMAGO. (L. *imago*, an image.) Applied by Linnæus to the perfect, winged, sexual insect.

IMBRICATED. (L. *imbricatus*, tiled.) Applied to scales or plates which overlap each other like the tiles of a house.

INCISOR. (L. *incido*, I cut.) The cutting teeth fixed in the front of the *Mammalian* jaws.

INEQUILATERAL. Having two unequal sides.

INEQUIVALVE. Having two unequal pieces or valves.

INFUNDIBULUM. (L. *infundibulum*, a funnel.) The tube or "funnel" composed of processes of the mantle of *Mollusca*, by means of which the water passes out from the branchial or respiratory chamber.

INFUSORIA. (L. *infusum*, an infusion.) A class of *Protozoic* animals, including microscopic animalculæ, and so called from their occurrence in infusions of organic matter.

INOPERCULATA. (L. *in*, without; *operculum*, a lid.) A section of terrestrial *Gasteropoda*, distinguished by the non-possession of a horny plate or "operculum" for closing the mouth of the shell.

INSECTA. (L. *inseco*, I cut in pieces.) A class of *Annulosa*, distinguished by the perfect segmentation of the body.

INSECTIVORA. (L. *insectum*, an insect; *voro*, I devour.) An order of *Mammalia*, represented by the Mole.

INSESSORES. (L. *insedeo*, I sit upon.) The order of perching or *Passerine* Birds.

INTERAMBULACRAL-AREAS. The spaces in the shell of the *Echinus*, composed of plates which are non-perforated for the protrusion of the tubular feet.

INVERTEBRATA. (L. *in*, without; *vertebra*, a segment of the spine.) Lamarck's division of the Animal Kingdom, including those animals destitute of a backbone.

ISOPODA. (G. *isos*, equal; *pous*, foot.) An order of *Crustacea* in which the feet are equal. Represented by the *Oniscus* or Wood Louse.

JUGULAR. (L. *jugulum*, the throat.) Applied to the ventral fins of Fishes when they are situated on the throat, and below or in front of the pectoral fins.

KAINOZOIC. (G. *kainos*, recent; *zoe*, life.) The most recent or Tertiary period of palæontologists, including those formations in which the fossils are those of, or approach nearly to, existing species of animals and plants.

KERATODE. (G. *keras*, horn; *eidos*, form.) The horny material of which sponge-fibres are in greater part composed.

Labium. (L. *labium*, a lip.) The lower lip of *Annulosa*.

Labrum. The upper lip of *Annulosa*.

Labyrinthodontia. (G. *labyrinthos*, a labyrinth ; *odous*, tooth.) An extinct order of *Amphibia*.

Lacertilia. (L. *lacerta*, a Lizard.) An order of Reptilia.

Lamella. (L. *lamella*, a plate.) A plate-like structure.

Lamellibranchiata. (L. *lamella ;* G. *bragchia*, gills.) A class of *Mollusca* distinguished by the possession of membranous lamellar or plate-like gills.

Larva. (L. *larva*, a mask.) The term applied by Linnæus to the grub or caterpillar, as forming the first stage in the metamorphosis of *Insecta*.

Larynx. The upper part of the trachea or wind-pipe, forming in the higher *Vertebrata* the organ of voice.

Lepidoptera. (G. *lepis*, a scale ; *pteron*, a wing.) An order of Insects represented by the Moths and Butterflies, distinguished by the possession of four scale-covered wings.

Lepidosiren. (G. *lepis*, and *seiren*, a siren.) A fish exemplifying the order *Dipnoi*.

Lingual. (L. *lingua*, the tongue.) Connected with the tongue.

Lophophore. (G. *lophos*, a crest ; *phero*, I carry.) The disc upon which the tentacles of the *Polyzoa* are supported.

Loricata. (L. *lorica*, a breastplate.) Applied to the division of *Reptiles*, including the Turtles and Crocodiles, in which the exoskeleton consists of bony plates. (Squamata.)

Lucernaria. (L. *lucerna*, a lamp.) A genus of *Hydrozoa*, representing the order *Lucernarida*.

Lumbar. (L. *lumbus*, the loins.) Connected with the loins.

Macrura. (G. *makros*, long ; *oura*, tail.) A section of *Crustacea* (*Decapoda*), represented by the Lobsters, etc., in which the tail is elongated.

Madreporiform. Perforated with small holes.

Madreporiform tubercle. The small perforated plate by which water is admitted to the ambulacral system of the *Echinozoa*.

Mallophaga. (G. *mallos*, a fleece ; *phago*, I eat.) An order of Insects parasitic upon Birds.

Mammalia. (L. *mamma*, a breast.) A class of *Vertebrata* possessing mammary or milk glands, by means of which they suckle their young.

Mandible. (L. *mandibulum*, a jaw.) The upper and larger pair of jaws in *Arthropodous Annulosa*. The lower jaw in *Vertebrata*.

Mantle. The external soft skin of *Mollusca*, which invests and envelopes the viscera. (Pallium.)

Marsipobranchii. (G. *marsipos*, a pouch ; *bragchia*, gills.)

An order of Fishes with pouch-like gills, represented by the Lampreys.

Marsupialia. (L. *marsupium*, a pouch.) An order of *Mammalia*, represented by the Kangaroos, etc., and distinguished by the possession of an abdominal pouch, in which the young are carried and protected.

Mastodon. (G. *mastos*, breast; *odous*, tooth.) An extinct genus of *Mammalia*, allied to the Elephants.

Maxillæ. (L. *maxilla*, a jaw.) The second and lesser pair of jaws in *Arthropodous Annulosa*. The superior jaw of *Vertebrata*.

Maxillipedes. Applied to the anterior modified limbs of *Crustacea*, which are converted into masticatory organs, and termed "foot-jaws."

Medulla. (L. *medulla*, marrow.) The marrow of bones. The spinal cord of *Vertebrata*.

Medusæ. A group of *Hydrozoa*, represented by the *Medusidæ*, or "Jelly Fishes."

Megatherium. (G. *mega*, great; *therion*, beast.) An extinct Mammal of large size, allied to the Sloths.

Mesentery. (G. *mesos*, intermediate; *enteron*, intestine.) The vertical plates which divide the body cavity of *Actinozoa* into "loculi," or chambers. The vascular membrane which connects the viscera of *Echinus* to the internal surface of the shell. The membrane supporting the digestive viscera of *Vertebrata*.

Mesothorax. (G. *mesos*; *thorax*, the chest.) The middle segment of the thorax in *Insecta*.

Mesozoic. (G. *mesos*; *zoe*, life.) The Secondary or Middle-life period of Palæontologists.

Metacarpus. (G. *meta*, after; *karpos*, the wrist.) The bones between the wrist or carpus, and the fingers or phalanges.

Metamorphosis. (G. *meta*, change; *morphe*, shape.) The series of changes undergone by the young of certain animals in their progress from the embryonic to the mature and adult state.

Metatarsus. (G. *meta*, after; *tarsos*, the flat of the foot.) The bones between those of the ankle and the phalanges of the toes.

Metathorax. (G. *meta*; *thorax*, the chest.) The posterior segment of the thorax in *Insecta*.

Molar. (L. *mola*, a mill.) The teeth of *Mammals*, which are not preceded by milk-teeth; the function of which is to "grind" the food.

Mollusca. (L. *mollis*, soft.) The sub-kingdom of animals represented by Shell Fish, Cuttlefishes, and allied forms.

Molluscoida. (*Mollusca*; G. *eidos*, form.) The lower section of *Mollusca*, including the *Polyzoa*, *Tunicata*, and *Brachiopoda*, and distinguished by the inferior organisation of the nervous and circulatory systems.

Monad. (G. *monas*, single.) Applied to organisms of microscopic size, and of low organisation, found in organic infusions.

Monodelphia. (G. *monos ; delphus*, the womb.) The section of *Mammalia*, including those forms in which the uterus is single. (Placentalia.)

Monomyaria. (G. *monos ; muon*, muscle.) Applied to those *Lamellibranchiata*, represented by the Oyster, in which in a single adductor muscle only exists.

Monophyodont. (G. *monos ; phuo*, I generate ; *odous*, tooth.) Applied to those *Mammalia*, in which a single set of teeth only is developed throughout life.

Monothalamous. (G. *monos ; thalamos*, chamber.) Applied to shells which consist of but a single chamber.

Monotremata. (G. *monos ; trema*, aperture.) An order of *Mammalia*, represented by the *Ornithorhynchus*, in which the urinary, alimentary, and generative systems open into a common chamber or "cloaca." (Ornithodelphia).

Morphology. (G. *morphe*, form ; *logos*, a discourse.) The division of biological science which investigates the form and disposition of organs and structures.

Multilocular. (L. *multus*, many ; *loculus*, a little purse.) Consisting of many chambers or compartments.

Multivalve. Applied to the shells of certain *Gasteropoda*, which consist of more than two pieces.

Myelon. (G. *muelos*, marrow.) The spinal cord of *Vertebrata*.

Myriapoda. (G. *murios*, numerous ; *poda*, feet.) A class of *Annulosa*, represented by the Centipedes, distinguished by the large number of feet.

Natatores. (L. *nato*, I swim.) The order of swimming Birds.

Nectocalyx. (G. *necho*, I swim ; *kalux*, cup.) The swimming bell or disc of *Hydrozoa*.

Nematelmia. (G. *nema*, thread ; *helmins*, a Worm.) An order of *Scolecida*, including the so-called "Round Worms," etc.

Nematocyst. (G. *nema ; kustis*, a bladder.) The "cnidæ" or thread-cells of *Cœlenterata*. (Cnidæ.)

Nemertida. (G. *Nemertes*.) A group of *Scolecida*, including the "Ribbon Worms."

Nerve. (L. *nervus*, a sinew.) Applied to the conducting filaments or branches of the nervous system.

Nervures. (L. *nervus*.) The supporting ribs of the wings of *Insecta*.

Neural. (G. *neuron*, a nerve.) Belonging to the nervous system.

Neurapophysis. (G. *neuron ; apophusis*, a projection.) The superior arches or processes which spring from the "centrum" or body of a vertebra, and which unite in the middle line to form the neural canal for the protection of the spinal cord.

NEUROPODIA. (G. *neuron ; pous*, the foot.) The inferior or ventral "oars" or "foot tubercles" of *Annelida*, so called from their position relative to the nervous system.

NEUROPTERA. (G. *neuron ; pteron*, wing.) An order of *Insecta*, represented by the Dragon Flies, etc., distinguished by the possession of four large membranous wings, supported by distinct "nervures."

NEUTER. (L. *neuter*, neither.) Applied specially to those Insects in which the sex is indistinct or undeveloped.

NICTITATING MEMBRANE. (L. *nicto*, I wink.) The third eyelid of Reptiles and Birds.

NOCTURNAL. (L. *nox*, night.) Applied to those forms which are active or move about during the night.

NORMAL. (L. *norma*, a rule or standard.) Agreeing with an ordinary type of structure or function.

NOTOBRANCHIATA. (G. *noton*, back ; *bragchia*, gills.) A group of the Annelida, in which the gills are borne on the upper or dorsal surface of the body.

NOTOCHORD. (G. *noton ; chorde*, a string.) Or "Chorda Dorsalis." An embryonic structure found in all *Vertebrates*, and formed in the floor of the "primitive groove." Replaced in the adult by the spinal column, of which the notochord is the early representative.

NOTOPODIUM. (G. *noton ; poda*, feet.) The superior or dorsal "oar," or foot tubercle of *Annelida*.

NUCLEATED. Possessing a nucleus or central solid particle.

NUCLEOLUS. (L. diminutive of *nucleus*, a kernel.) The speck or particle of solid matter found in the interior of the nucleus of cells.

NUCLEUS. (L. *nucleus*.) The particle of solid germinal matter found in the interior of cells, and with which the development of cells is intimately associated.

NUDIBRANCHIATA. (L. *nudus*, naked ; G. *bragchia*, gills.) A division of *Gasteropoda*, in which the gills are unprotected.

NYMPHS. The pupa of Insects, which are active during the chrysalis or pupa stage of their development.

OCCIPITAL. Belonging to the "occipital" bone, or back part of the head.

OCELLI. (L. *ocellus*, a little eye.) The simple eyes of *Cœlenterata*, *Echinodermata*, *Annulosa*, and *Mollusca*.

OCTOPODA. (G. *octo*, eight ; *poda*, feet.) A division of the *Dibranchiate Cephalopoda*, including those Cuttlefishes which possess eight arms or tentacles.

Odontophore. (G. *odous*, tooth; *phero*, I bear.) The masticatory "tongue," or lingual ribbon of *Mollusca*.

Odontophora. (G. *odous; phero.*) Applied collectively to those classes of Mollusca which possess distinct heads, and in which an "odontophore" is also present.

Œsophagus. (G. *oisos*, a reed; *phagein*, to eat.) The "gullet," or tube leading from the mouth to the stomach.

Oligochætæ. (G. *oligos*, few; *chaite*, hair.) An order of *Annelida*, represented by the Earthworms, in which few locomotive bristles are developed.

Oolite. A series of strata of the *Mesozoic* period.

Operculata. (L. *operculum*, a lid.) A division of *Pulmonary Gasteropoda*, in which the shell is closed by an "operculum."

Operculum. (L. *operculum.*) A horny or calcareous plate borne on the "foot" of *Gasteropodous Mollusca*, by means of which the aperture of the shell is closed when the animal is retracted within its abode. Applied to the movable piece of the shell in certain *Crustaceans*, such as *Balanus*. The bony flap of Fishes covering the gills, and forming the external covering of the branchial or gill-chamber.

Ophidia. (G. *ophis*, a serpent.) An order of *Reptilia*, including the snakes.

Ophiomorpha. (G. *ophis; morphe*, shape.) A division of *Amphibia*, represented by the *Cœciliadœ*.

Ophiura. (G. *ophis: oura*, a tail.) A genus of *Echinodermata*, represented by the "Brittle Stars," which form the type of the order *Ophiuroidea*.

Opisthobranchiata. (G. *opisthen*, behind; *bragchia*, gills.) A group of *Gasteropoda*, in which the gills are situated towards the posterior aspect of the body.

Opisthocœlous. (G. *opisthen; koilos*, hollow.) Applied to those vertebræ the bodies of which are hollow or concave posteriorly.

Oral. (L. *os*, mouth.) Belonging to the mouth.

Ornithodelphia. (G. *ornithos*, a bird; *delphus*, the womb.) A sub-class of *Mammalia*, including the *Ornithorhynchus*. (Monotremata.)

Ornithorhynchus. (G. *ornithos; rhunchos*, beak.) A genus of *Monotremata*, familiarly known as the *Duck-billed Platypus*, or "Water-mole" of Australia.

Orthoptera. (G. *orthos*, straight; *pteron*, wing.) An order of *Insecta*, represented by Locusts, etc., characterised by the "straight" arrangement of the wing-nervures.

Oscula. (L. *osculum*, a little mouth.) The larger "exhalent" apertures of *Spongida*.

OTOLITHS. (G. *ous*, ear; *lithos*, stone.) Calcareous particles enclosed in the auditory capsules of *Invertebrata*.

OVARY. The essential element of the female reproductive system, in which the "ova" or eggs are developed.

OVIPAROUS. (L. *ovum*, an egg; *pario*, I produce.) Producing eggs. Specially applied to those *Vertebrata* in which the ova are expelled from the parent body before or soon after impregnation.

OVIPOSITOR. (L. *ovum; pono*, I place.) The abdominal terminal appendages of certain *Insects*, by means of which the eggs are deposited or placed in situations favourable for development.

OVUM. (L. *ovum*.) The "ovum" or egg, representing the essential contribution of the female in the reproductive process, and which, after impregnation, is capable of evolving a new form or "individual."

OXYURIS. (G. *oxus*, sharp; *oura*, tail.) The genus of "Threadworms," included in the *Nematelmia*.

PACHYDERMATA. (G. *pachus*, thick; *derma*, skin.) An order of *Mammalia* now included in the *Ungulata*, and which was represented by the Elephants and allied forms.

PALÆONTOLOGY. (G. *palaios*, ancient; *logos*, a discourse.) A division of science which investigates extinct and fossil organic remains.

PALÆOTHERIUM. (G. *palaios; therion*, beast.) An extinct *Ungulate Mammal* allied to the Tapirs, and belonging to the Tertiary epoch.

PALÆOZOIC. (G. *palaios; zoe*, life.) The most ancient of the epochs into which the series of rock formations is divided.

PALLIAL. Belonging to the "mantle."

PALLIOBRANCHIATA. (L. *pallium;* G. *bragchia*, gills.) A term formerly applied to the *Brachiopodous Mollusca*, in allusion to the erroneous supposition that the mantle formed the respiratory organ in these forms.

PALLIUM. (L. *pallium*, a cloak.) The "mantle" of *Mollusca*, or membrane which secretes the shell.

PALPI. (L. *palpo*, I touch.) Appendages attached to the masticatory organs of *Insecta*, *Arachnida*, and *Crustacea*, and which are supposed to subserve the sense of touch.

PARAPODIA. (G. *para*, beside; *poda*, feet.) The lateral processes of *Annelida*, otherwise known as "foot-tubercles."

PARIETAL. (L. *paries*, a wall.) Belonging to the walls or sides of any cavity or structure.

PARIETO-SPLANCHNIC. (L. *paries;* G. *splagchna*, viscera). The nervous ganglion in the higher *Mollusca* which supplies the mantle, gills, and viscera generally.

PATAGIUM. (G. *patageion*, the border of a dress.) Applied to the expansion of the skin or integument by which certain animals (Flying Dragon, Bats, Flying Lemurs, etc.) support themselves in the air.

PATELLA. The knee-pan or knee-cap.

PECTORAL. (L. *pectus*, the breast.) Belonging to the chest.

PEDAL. (L. *pes*, the foot.) Relating to the "foot" of *Mollusca*. Connected with the foot.

PEDICELLARIÆ. (L. *pedicellus*, a Louse.) Minute organic appendages found attached to the external surface of most *Echinodermata*.

PEDIPALPI. (L. *pes*, the foot; *palpo*, I feel.) A term sometimes applied to the order of *Arachnida*, including the Scorpions, and so called from the great development of the maxillary palpi.

PEDUNCLE. (L. *pedunculus*, a stalk.) The stalk by which certain *Brachiopoda* are attached to fixed objects. The stalk of *Cirripedes*. Ex. Barnacles.

PELAGIC. (G. *pelagos*, sea.) Applied to those forms which inhabit the open sea.

PELVIS. (L. *pelvis*, a basin.) The "hip-girdle" or bony arch supporting the hinder or pelvic limbs of *Vertebrata*.

PERENNIBRANCHIATA. (L. *perennis*, perpetual; G. *bragchia*, gills.) A group of *Amphibia* in which the gills are persistent throughout life.

PERICARDIUM. (G. *peri*, around; *kardia*, heart.) The serous membrane which envelopes the heart in the higher animals. Applied to a large venous canal or "sinus" surrounding the heart of *Crustacea*.

PERIGASTRIC. (G. *peri*; *gaster*, stomach.) Applied to spaces in the body-cavity of *Invertebrates* which surround the stomach and viscera generally, and through which a distinct circulation or "cyclosis" is in some cases maintained.

PERISSODACTYLA. (G. *perissos*, uneven; *daktulos*, toe.) Applied to those *Ungulate* or "Hoofed" Quadrupeds, in which the feet have an odd number of digits. Ex. Tapir, Horse.

PERIVISCERAL. (*See* PERIGASTRIC.)

PHALANGES. (G. *phalagx*, a row.) The small bones composing the digits (or fingers and toes) of the higher *Vertebrata*.

PHARYNGOBRANCHII. (G. *pharugx*, the pharynx; *bragchia*, gills.) An order of Fishes, including only the Lancelet, in which the perforated pharynx performs the function of gills.

PHARYNX. (G. *pharugx*.) The upper part of the gullet.

PHRAGMACONE. (G. *phragma*, a partition; *konos*, a cone.) The chambered portion of the shell of the *Belemnitidæ*.

PHYLACTOLÆMATA. (G. *phulaktos*, guarded; *laimos*, throat.) An order of *Polyzoa*, in which the oral opening is guarded by an epistome.

PHYSOPHORIDÆ. (G. *phusa*, bellows; *phero*, I carry.) An order of *Hydrozoa*, distinguished by the possession of a "pneumatophore," or "float."

PHYTOPHAGOUS. (G. *phuton*, a plant; *phago*, I eat.) Applied to those animals which subsist on a vegetable diet.

PINNATE. (L. *pinna*, a feather.) Feather-shaped.

PINNIGRADA. (L. *pinna*; *gradior*, I walk.) A group of *Carnivorous Mammals*, represented by the Seals and Walruses, in which the feet are in the form of swimming paddles.

PISCES. (L. *piscis*, a fish.) A class of *Vertebrata*, including the Fishes.

PLACENTA. (L. *placenta*, a cake.) Applied to the "after-birth," or organ by means of which a vascular connection is maintained between the fœtus and mother before birth.

PLACOID. (G. *plax*, a plate; *eidos*, form.) Applied to the bony plates or scales found irregularly disposed over the skin of certain Fishes, such as Sharks, Rays, etc.

PLAGIOSTOMI. (G. *plagios*, transverse; *stoma*, mouth.) A division of *Elasmobranchii*, including the Sharks and Rays, in which the mouth is transverse, and situated on the under surface of the head.

PLANTIGRADE. (L. *planta*, the sole of the foot; *gradior*, I walk.) A division of *Carnivora*, in which the whole of the foot is applied to the ground in walking. Ex. Bears.

PLATYELMIA. (G. *platus*, broad; *helmins*, a worm.) A group of *Scolecida*, including the "Tape" or Flat Worms.

PLATYRHINA. (G. *platus*, broad; *rhines*, nostrils.) A division of *Quadrumana*, in which the nostrils are broad and placed widely apart. Ex. Spider-monkeys.

PLESIOSAURUS. (G. *plesios*, near; *saura*, a Lizard.) An extinct genus of marine *Reptiles*, representing the order *Plesiosauria*.

PNEUMATIC. (G. *pneuma*, air). Applied to cavities or structures filled with air.

PNEUMATOPHORE. (G. *pneuma*; *phero*, I carry.) The "float" or dilated portion of the cœnosarc in *Physophoridæ*, by means of which these oceanic forms float on the surface of the sea.

PODOPHTHALMIA. (G. *pous*, foot; *ophthalmos*, eye.) An order of *Crustacea* (*Decapoda*), in which the eyes are pedunculated or stalked.

POLLEX. (L. *pollex*, the thumb.) The first or innermost digit of the pectoral limb of *Vertebrata*—the thumb.

POLYGASTRICA. (G. *polus*, many; *gaster*, belly or stomach.) A name applied erroneously by Ehrenberg to the *Infusoria*.

POLYPARY. The chitinous secretion investing the "hydrosoma" of many *Hydrozoa*.

POLYPE. (G. *polus*, many; *pous*, foot.) Now applied to the "individuals" of single *Actinozoa*, or to the "Zoöids" of a compound *Actinozoön*. Broadly used to signify any of the plant-like *Protozoa* and *Cœlentèrata*.

POLYPIDE. Applied to the individual zoöids of a *Polyzoön*.

POLYPIDOM. The common integumentary structure of a compound Hydrozoön or Polyzoön.

POLYPITE. Applied to the individual zoöids of a *Hydrozoön*.

POLYTHALAMOUS. (G. *polus*, many; *thalamos*, chamber.) Many-chambered; applied to the shells of *Foraminifera*.

POLYZOA. (G. *polus*, many; *zoön*, animal.) A class of *Molluscoida*, represented by compound forms (*Flustræ* or "Sea-Mats"). The term *Bryozoa* is sometimes applied to this class.

POLYZOARIUM. The common integumentary system or structure of a *Polyzoön*.

PORIFERA. (L. *porus*, a pore; *fero*, I carry.) An old term applied to the *Sponges*.

POST-ŒSOPHAGEAL. Situated posteriorly to or behind the gullet.

PRÆMOLAR. (L. *præ*, in front; *molares*, grinders.) The "Bicuspid" teeth; or those "Molars" which are preceded by deciduous or Milk-teeth.

PRÆ-ŒSOPHAGEAL. Situated anteriorly to or in front of the gullet.

PROBOSCIDEA. (L. *proboscis*, the snout.) A division of hoofed *Quadrupeds*, represented solely by the Elephants, and distinguished by the possession of a proboscis.

PROCŒLOUS. (G. *pro*, front; *koilos*, hollow.) Applied to those vertebræ, the bodies of which are concave or hollow in front.

PROGLOTTIS. (G. *proglottis*, the point of the tongue.) Applied to the generative segments or zoöids of *Scolecida*, produced by gemmation, and containing ova. Ex. Tape-worm.

PROLEGS. False or abdominal legs of *Lepidopterous* larvæ.

PROPODITE. (G. *pro*, front; *pous*, foot.) The proximal segment of the typical limb of *Crustacea*.

PROSCOLEX. (G. *pro*, before; *skolex*, worm.) The first stage in the development of a Tape-worm, represented by the early embryo liberated from the ovum.

PROSOBRANCHIATA. (G. *proson*, in advance of; *bragchia*, gills.) A division of *Gasteropoda*, in which the gills are situated anteriorly to the heart.

PROTHORAX. (G. *pro*, before; *thorax*, the chest.) The anterior segment of the thorax in *Insecta*.

PROTISTA. A term applied by Häckel to a division, including those lower organisms, the exact nature of which (plant or animal) has not been certainly ascertained.

PROTOPHYTA. (G. *protos*, first; *phuton*, plant.) A collective term, applied to the lower orders of plants.

PROTOPLASM. (G. *protos; plasso*, to form.) "The primitive indifferent tissue of the embryo." The elementary or primitive basis of organised beings and tissues. The physical basis of life. Sometimes also called "sarcode" or "bioplasm."

PROTOZOA. (G. *protos; zoön*, animal.) The lowest sub-kingdom of animals.

PROVENTRICULUS. (L. *pro*, in front of; *ventriculus*, diminutive of *venter*, belly.) The anterior portion of the stomach in Birds, corresponding to the cardiac part of the stomach in the higher animals.

PROXIMAL. (L. *proximus*, next.) The fixed extremity of a limb or organism.

PSALTERIUM. (L. *psalterium*, a stringed instrument.) The third compartment of the Ruminant stomach.

PSEUDOHÆMAL. (G. *pseudos*, false; *haima*, blood.) A term applied to the blood-vascular system of *Annelida*.

PSEUDONAVICELLÆ. (G. *pseudos; navicula*, a little boat.) Applied to the embryos of *Gregarinida*, in allusion to their boat-like shape.

PSEUDOPODIA. (G. *pseudos; poda*, feet.) The prolongations of the protoplasmic body of the *Rhizopoda*, which can be thrust out or drawn in at will.

PTERODACTYLA. (G. *pteron*, wing; *daktulos*, finger.) An order of extinct *Reptiles*.

PTEROPODA. (G. *pteron; poda*, feet.) A class of *Mollusca*, distinguished by the presence of two wing-like fins attached to the head.

PTEROSAURIA. (*See* PTERODACTYLA.)

PULMONARIA. (L. *pulmo*, a lung.) A section of *Arachnida*, possessing pulmonary or lung sacs.

PULMONIFERA. (L. *pulmo; fero*, I carry.) A division of *Gasteropodous Mollusca*, which breathe by means of a pulmonary sac or chamber.

PUPA. (L. *pupa*, a doll.) The second and usually quiescent stage in the metamorphosis of *Insecta*, sometimes called "nymph" or "chrysalis."

PYLORUS. (G. *puloros*, a gate-keeper.) Applied to the valvular structure between the stomach and intestine.

QUADRATUM OS. The bone by which the lower jaw in *Sauropsida* articulates with the skull.

QUADRUMANA. (L. *quatuor*, four; *manus*, hand.) An order of *Mammalia*, including the Apes, Monkeys, and Lemurs.

RADIATA. (L. *radius*, a spoke, or ray.) A term applied by Cuvier to a sub-kingdom of animals now included under the *Protozoa*, *Cœlenterata*, and *Echinozoa*.

Radiolaria. (L. *radius.*) A group of *Protozoa.*

Radius. (L. *radius.*) The bone of the forearm in the higher *Vertebrata,* which articulates with the pollex or thumb.

Ramus. (L. *ramus,* a branch.) Applied to each half of the lower jaw in *Vertebrates.*

Raptores. (L. *rapto,* I steal.) An order of Birds, including the Birds of prey.

Rasores. (L. *rado,* I scratch.) An order of Birds, including the common Fowl and its allies, distinguished by their scratching habits. Otherwise known as the *Gallinacei.*

Ratitæ. (L. *ratis,* a raft.) A term applied by Huxley to the *Cursores,* or running Birds, in allusion to the "keel-less" character of the sternum or breast-bone.

Rectum. (L. *rectus,* straight.) The terminal portion of the intestine, so named from its usually short and straight course.

Regnum Protisticum. Häckel's division of organic things, formed to include certain low organisms, concerning the true nature of which some doubt exists.

Renal. (L. *ren,* a kidney.) Pertaining to the urinary function.

Reptilia. (L. *repto,* I crawl.) A class of *Vertebrata,* including the Turtles, Serpents, Crocodiles, and Lizards.

Reticulum. (L. *reticulum,* a net.) The second compartment of the *Ruminant* stomach, so named from the reticulated or network appearance of its internal surface. Otherwise known as the "Honeycomb."

Rhizopoda. (G. *rhiza,* root; *poda,* feet.) A class of *Protozoa,* represented by the *Amœba,* in which the sarcode of the body is capable of being protruded in the form of pseudopodia.

Rodentia. (L. *rodere,* to gnaw.) An order of *Mammalia,* represented by the Rats, Beavers, etc.

Rostrum. (L. *rostrum,* a beak.) Applied to the anterior spine of the carapace in *Crustacea,* and to the suctorial apparatus of the mouth in certain *Insecta.*

Rotifera. (L. *rota,* a wheel; *fero,* I bear.) A class of *Animalcules,* now included in the sub-kingdom *Echinozoa,* and distinguished by the possession of an anterior ciliated disc.

Rugosa. (L. *rugosus,* wrinkled.) An order of extinct corals (*Actinozoa*).

Rumen. (L. *rumen,* the throat.) The first compartment of the *Ruminant* stomach, otherwise known as the "paunch."

Ruminantia. (L. *ruminor,* I chew the cud.) An order or group of *Mammalia,* including those forms which "ruminate" or "chew the cud."

Sacrum. Applied collectively to the vertebræ which usually unite to form a single bone, and which in turn forms part of the pelvis.

SARCODE. (G. *sarx*, flesh; *eidos*, form.) (*See* PROTOPLASM.)

SAURIA. (G. *saura*, a Lizard.) A term sometimes applied to the Crocodiles and Lizards, as forming the Lizard-like Reptiles.

SAUROPSIDA. (G. *saura; opsis*, appearance.) A province of *Vertebrata* including the Reptiles (*Reptilia*) and Birds (*Aves*).

SAURURÆ. (G. *saura; oura*, tail.) An order of Birds represented only by the extinct *Archæopteryx*, distinguished by the possession of a long Lizard-like tail.

SCANSORES. (L. *scando*, I climb.) An order of Birds represented by the Parrots, distinguished by their climbing habits.

SCAPHOGNATHITE. (G. *skaphos*, boat; *gnathos*, jaw.) The appendage or epipodite of the second pair of maxillæ in the Lobster, etc. Used to bale out the water from the respiratory or branchial chamber.

SCAPULA. The "shoulder-blade," one of the elements of the pectoral arch of *Vertebrata*.

SCLEROBASIC. (G. *skleros*, hard; *basis*, column.) The coral produced by the outer layer of the integument in *Actinozoa*, and which exists as a solid central stem or axis enveloped by the soft tissues of the animal.

SCLERODERMIC. (G. *skleros; derma*, skin.) Applied to the coral-structures secreted *within* the tissues of *Actinozoa*.

SCLEROTIC. (G. *skleros*.) The outer fibrous capsule of the eye, which, in certain instances, bears osseous developments in its substance.

SCOLECIDA. (G. *skolex*, a worm.) A class of *Echinozoa*, including the *Entozoa* of some authors, and represented by parasitic worms.

SCOLEX. (G. *skolex*.) The larval stage of the *Scolecida*, otherwise known as a *Cystic Worm*.

SCUTUM. (L. *scutum*, a shield.) Applied to the bony plates developed in the dermis or true skin of certain Reptiles, such as the *Crocodiles*.

SEPTA. (L. *septum*, a partition.) Applied to any partition-like structures or dividing membranes.

SERTULARIDA. (L. *sertum*, a wreath; G. *eidos*, form.) An order of *Hydrozoa*.

SESSILE. (L. *sedo*, I sit.) Applied to any structures or forms which are attached directly, or without the intervention of a peduncle or stalk.

SETÆ. (L. *seta*, a bristle.) Bristles or hair-like processes.

SILICEOUS. (L. *silex*, flint.) Composed of flint.

SINUS. (L. *sinus*, a bay.) Applied to the large venous receptacles which exist in the neighbourhood of the heart and respiratory organs in *Invertebrata*. Otherwise applied to any large channel having an undefined course or boundary line.

Siphon. (G. *siphon*, a tube.) The respiratory tubes of certain *Molluscs*.

Siphonostomata. (G. *siphon; stoma*, mouth.) A division of *Gasteropoda* in which the aperture of the shell is indented by a notch for the protection of a respiratory tube or siphon.

Sipuncle. (L. *sipunculus*, a little tube.) The tube, by means of which communication is maintained between the chambers of the shell in certain *Cephalopoda*.

Sirenia. (G. *Seiren*, a mermaid.) An order of *Mammalia*, represented by the Dugongs, etc.

Solidungula. (L. *solidus*, solid; *ungula*, a hoof.) The division of *Ungulate* or "Hoofed" Quadrupeds, including the Horse, in which the toes are enclosed in a single and solid hoof.

Somatic. (G. *soma*, body.) Belonging to the body.

Somite. (G. *soma*.) Applied to the segments of *Annulose* bodies; but also to the individual segments or joints of a connected series.

Specialisation of Function. A term employed to indicate the growth in complexity of a function or series of functions in living bodies, the essential of the definition being the superadding of new organs and new parts as the function becomes divided in turn. Thus the digestive system of a *Mammal* is more specialised than that of a Worm; *i.e.*, the function is more complex, and its various parts are subserved each by special organs. Milne Edwards' term, the "physiological division of labour," well explains the meaning of the expression.

Spermarium. (G. *sperma*, seed.) The organ by which the essential element or "spermatic fluid" of the male is produced.

Spermatozoa. (G. *sperma; zoön*, animal.) The minute animalcules found in the "spermatic fluid" of the male, and in which it is supposed the essential element of the male resides.

Spicula. (L. *spiculum*, a point.) Pointed, or spindle-shaped bodies. Usually applied to the calcareous particles found in Sponges.

Spinneret. The organ by means of which the thread-secretion of Spiders, etc., is produced.

Spiracles. (L. *spiro*, I breathe.) The external openings of the respiratory tubes of Insects; also applied to the breathing-holes of certain Fishes, and to the nostrils of certain *Cetacea*.

Spongida. (G. *spoggos*, a sponge.) A class of *Protozoa*, familiarly known as Sponges.

Spores. (G. *spora*, seed.) Applied to the generative seeds or "gemmules" of certain *Protozoa*.

Squamata. (L. *squama*, a scale.) Applied to certain *Reptiles* (Snakes and Lizards), in which epidermic scales are developed. (Loricata.)

Statoblasts. (G. *statos*, fixed; *blastos*, a bud.) Reproductive bodies found in certain *Polyzoa*, which only undergo development when set free from the organism in which they are produced.

Sternum. The "breast-bone" of higher *Vertebrata*. Or the lower or ventral pieces of the typical segments in *Crustacea*.

Stigmata. (G. *stigma*, a mark.) (*See* Spiracles.)

Stolon. (G. *stolos*, a branch.) The connecting basal processes or "roots," by means of which the zooids of certain *Actinozoa* and *Tunicata* are bound together.

Stomapoda. (G. *stoma*, mouth; *poda*, feet.) An order of *Crustacea*, distinguished by the possession of foot-like oral appendages. Ex. *Squilla*.

Stomatous. (G. *stoma*.) Applied to the *Infusoria*, as distinguished from other *Protozoa*, by the possession of a mouth.

Strepsiptera. (G. *strepho*, I twist; *pteron*, wing.) An order of *Insecta*, in which the place of the anterior wings is supplied by a pair of twisted filaments.

Strepsirhina. (G. *strepho; rhines*, nostrils.) A group of *Quadrumana*, represented by the Aye-aye, in which the nostrils are twisted or curved.

Strobila. (G. *strobilos*, a fir-cone.) The chain of zoöids formed by a "Scolex," and the "proglottides," which have been produced therefrom by "gemmation." The adult Tape-worm (*Tænia*).

Suture. (L. *suo*, I sew.) The line of union or junction of two parts. Applied to the lines of junction of the bones of the *Vertebrate* skull; or to the lines formed by the margins of the "septa" on the external surface of certain *Cephalopodous* shells.

Swimmerets. Those limbs in *Crustacea* which subserve the function of natatory organs.

Symphysis. (G. *sumphusis*, a growing together.) The union of two bones, between which little or no motion can take place—*e.g.* the halves of the lower jaw in *Mammalia*.

Systole. (G. *sustello*, I contract.) The contraction of any muscular chamber or cavity, such as the heart.

Tabulæ. (L. *tabula*, a tabulet.) Transverse plates which divide the "thecæ" of certain corals horizontally.

Tactile. (L. *tango*, I touch.) Relating to the sense of touch.

Tænia. (G. *tainia*, a ribbon.) A genus of *Scolecida* (Tape-worm).

Tarso-metatarsus. The single bone forming the leg of Birds, and consisting of the united tarsus and metatarsus.

Tarsus. (G. *tarsos*, the flat of the foot.) The small bones forming the heel and ankle or "instep."

TECTIBRANCHIATA. (L. *tectus*, covered; G. *bragchia*, gills.) A division of *Gasteropoda*, in which the gills are concealed by the "mantle."

TELEOSTEI. (G. *teleios*, perfect; *osteon*, bone.) An order of Fishes with perfectly ossified skeletons.

TELSON. (G. *telson*, end.) The last segment in the tail or abdomen of *Crustacea*.

TENUIROSTRES. (L. *tenuis*, slender; *rostrum*, beak.) A division of the *Insessorial* or Perching Birds, in which the beak is of slender conformation.

TERGUM. (L. *tergum*, the back.) The upper or dorsal portion of the segments of a typical *Annulose* animal.

TEST. (L. *testa*, a shell.) Applied to the shell of *Echinodermata;* to the outer layer of the *Ascidian* "tunic;" and to the shell of ordinary *Mollusca*.

TESTIS. (L. *testis*, the testicle.) The organ in the male animal which produces the "spermatic fluid" or "semen."

TETRABRANCHIATA. (G. *tetra*, four; *bragchia*, gills.) An order of *Cephalopoda*, distinguished by the possession of four gills.

THECODONT. (G. *theke*, a case; *odous*, tooth.) Having teeth implanted in distinct "alveoli" or sockets.

THECOSOMATA. (G. *theke; soma*, body.) An order of *Pteropoda*, distinguished by the possession of an external shell.

THORAX. (G. *thorax*, a breastplate.) Applied in *Vertebrata* to the part of the trunk above the diaphragm, and in *Insects* to the central part of the body composed of three segments.

THREAD-CELLS. (*See* CNIDÆ.)

THYSANURA. (G. *thusanos*, a tassel; *oura*, tail.) An order of Insects.

TIBIA. (L. *tibia*, a flute.) The "shin-bone," or principal bone of the leg, corresponding with the radius of the pectoral limb.

TRACHEA. (G. *tracheia*, the rough windpipe.) In the higher *Vertebrata* the tube conveying air to the lungs. In *Insecta* the air-tubes or breathing-tubes which ramify through the body.

TRACHEARIA. A division of *Arachnida*, in which the respiration is carried on by means of air-tubes (*tracheæ*).

TREMATODA. (G. *trema*, an aperture.) A group of *Scolecida*.

TRICHINA. (G. *trichinos*, from *thrix*, hair.) A minute *Nematoid* worm, parasitic in human muscle.

TRILOBITA. (G. *treis*, three; *lobos*, a lobe.) A group of *Crustacea*, represented solely by extinct forms.

TROPHI. (G. *trophos*, a nourisher.) The oral appendages of *Insects* which are more immediately concerned in the prehension of food.

TROPHOSOME. (G. *trepho*, I nourish; *soma*, body.) Applied to the nutritive elements of a Hydrozoön, in contradistinction to the generative elements, which are accordingly denominated the "gonosome."

TUBICOLA. (L. *tuba*, a cylinder; *colo*, I inhabit.) An order of *Annelida* inhabiting tubes which they themselves secrete.

TUNICATA. (L. *tunica*, a garment.) A class of *Molluscoida*, so called from the fact of the body being enveloped in a chitinous or horny "test."

TURBELLARIA. (L. *turba*, a crowd.) A group of *Scolecida*.

ULNA. (G. *olene*, the elbow.) The outer of the two bones of the forearm, corresponding to the fibula in the pelvic limb.

UMBILICUS. (L. *umbilicus*, the navel.) The opening at the base of the columella of *Gasteropodous* shells.

UMBO. (L. *umbo*, the boss of a shield.) The beak or projection on the valves of *Lamellibranchiate* shells.

UMBRELLA. The disc of many *Hydrozoa*, by the contraction and expansion of which locomotion is effected through the water.

UNGULATA. (L. *ungula*, a hoof.) An order of *Mammals*, including the majority of Hoofed quadrupeds.

UNILOCULAR. (L. *unus*, one; *loculus*, a little purse.) Consisting of one cavity or chamber.

UNIVALVE. (L. *unus*; *valvæ*, folding doors.) Applied to shells consisting of a single piece or valve.

URODELA. (G. *oura*, tail; *delos*, visible.) An order of *Amphibia*, comprising those forms in which the tail is persistent in the adult state.

VACUOLES. (L. *vacuus*, empty.) Applied to minute empty spaces seen in the sarcode of the bodies of certain *Protozoa*, but especially in the *Infusoria*. Caused by the presence of food particles, surrounded by water.

VASCULAR. (L. *vas*, a vessel.) Applied to the hæmal or circulatory system. A tissue or structure is said to be vascular when it is richly supplied with bloodvessels.

VENTRAL. (L. *venter*, the belly.) Belonging to the inferior aspect of the body.

VENTRICLE. (L. diminutive of *venter*.) Any hollow space, but specially applied to the larger chambers of the heart.

VERMES. (L. *vermis*, a worm.) Occasionally employed to designate the class *Annelida*, or to the *Scolecida* (*Echinozoa*.)

VERTEBRA. (L. *vertere*, to turn.) One of the separate bones or segments of the vertebral column, spine, or backbone.

VERTEBRATA. (L. *vertere*, to turn.) A sub-kingdom of animals distinguished by the possession of a backbone.

Vesicle. (L. *vesica*, a bladder.) A small sac or cyst.

Vibracula. (L. *vibro*, to quiver.) Applied to filamentous appendages attached to many *Polyzoa*.

Vibriones. (L. *vibro*.) Applied to minute organisms, supposed to be of vegetable nature, found developed in infusions of organic matter.

Viperina. (L. *vipera*, a viper.) A sub-order of the *Ophidia* or Snakes.

Viviparous. (L. *vivus*, alive; *pario*, I bring forth.) Applied to those animals which bring forth their young alive.

Xiphosura. (G. *xiphos*, a sword; *oura*, tail.) An order of *Crustacea*, represented by the *Limuli* or King Crabs.

Zoöid. (G. *zoön*, animal; *eidos*, resemblance.) A term applied to the individual organisms produced by budding from a parent organism, and applied to such organisms whether connected with the parent body, or living a free and separate existence.

Zoophyte. (G. *zoön*; *phuton*, plant.) A term popularly and collectively applied to those animal forms which resemble plants in shape or appearance.

Zygapophysis. (G. *zugon*, a yoke; *apophusis*, an outgrowth.) A name given to the articulating processes of the vertebræ or segments of the backbone, and by means of which they are articulated to each other.

INDEX.

AARDVARK, 498
Abdomen of *Insecta*, 150, 158
Abdominalia (Fishes), 366
Abdominal pore, 352, 353
Abductor muscles (Mollusca), 235
Abomasum, 516
Abranchiata (Annelida), 139
Abranchiata (Vertebrata), 327, 390
Absorptive system, 317
Acanthocephala, 128
Acanthopteri, 367 ; *veri*, 367
Acarina, 188
Acarus, 188
Accipenser, 332, 361, 365
Accipitrinæ, 466
Acephala (Mollusca), 241, 242
Acetabula, 277
Achetina, 171
Acineta, 51, 53, 54
Acorn Shells, 195, 198
Actinia, 75, 76, 78
Actinidæ, 78
Actinophrys, 38
Actinosoma, 78
Actinozoa, 57 ; general characters of, 75 ; classification of, 77, 95
Aculeus, 178
Adductor muscles (Mollusca), 235, 244
Æolidæ, 265
Agassiz, 331
Age of Brachiopods, 239
Ai, 496
Air bladder of Fishes, 344
Air cells of Birds, 447, 448
Alcedinidæ, 465
Alces, 519
Alcidæ, 455
Alcyonaria, 88
Alcyonidæ, 88
Alcyonium, 88
Algæ, 5
Allantois, 329, 390
Alligator, 421
Allman, 22, 219, 227, 465
Alpaca, 518
Alternation of generations, 64, 72, 232
Alula, 429, 437
Alveolus, 281, 393, 474
Ambergris, 507
Ambulacra, 102, 106
Ambulacral system, 98, 99, 102, 105 ; areas, 100
Ameividæ, 413
Ametabolic *Insecta*, 162, 166, 167
Ammodytes, 366
Ammonite, 295, 296
Ammonitidæ, 295, 296, 297
Amnion, 329, 390
Amœba, 14, 30, 31, 34, 36, 37
Amœbea, 37
Amphibia, blood corpuscles of, 318, 319 ; characters of, 370 ; circulation in, 376 ; classification of, 381 ; endo-skeleton of, 373 ; respiration of, 377 ; metamorphosis of, 379

Amphicœlous vertebræ, 333, 373, 392, 417
Amphicœlia, 421
Amphioxus, 306, 320, 333, 350
Amphipoda, 195, 204
Amphisbænidæ, 412
Amphiuma, 384
Anacanthini, 366
Anal fin, 338
Analogy, 21
Anarthropoda, 135, 136; classification of, 136
Anatidæ, 453, 455
Anatomy, 10, 11
Ancyloceras, 297
Anguis, 412
Animals and Plants, differences between, 5
Annelida, 136; classification of, 139
Annuloida, 19, 97
Annulosa, characters of, 19, 133, 134; classification of, 135, 214
Anomura, 212
Anoplotherium, 512
Anoplura, 168
Anoura, 381, 385
Anserinæ, 455
Ant-eaters, 495, 496, 497, 498
Antelopes, 520
Antennæ, 144, 148, 151
Antennules, 211
Anthropomorpha, 567
Anthropoidea, 562
Anthropoid Apes, 567, 568
Anthropidæ, 562
Antilopidæ, 520
Antipathidæ, 87
Antlers, 518
Antlia, 154, 155
Antocular membrane, 395, 412
Ants, 178, 179
Apes, 563, 566
Aphaniptera, 174
Aphides, 169, 170
Aphrodita, 145
Aphroditidæ, 145
Apical canals, 94
Apidæ, 178
Aplacentalia, 481
Aplysiadæ, 264
Apoda (Fishes), 366 (Amphibia), 382
Appendicular elements of skeleton, 306
Aptera, 157, 166, 167
Apterygidæ, 458
Apteryx, 456, 457, 458
Arachnida, 147, 148, 182; classification of, 187
Araneina, 191
Archæopteryx, 466
Arctisca, 188
Arctomys, 550
Ardeidæ, 456
Arenicola, 144
Arenicolidæ, 144
Argonauta, 275, 279, 290; hectocotylus of, 287, 288, 292
Argonautidæ, 290
Argyroneta, 193
Aristotle's Lantern, 104
Armadillos, 495, 496
Arterial bulb of Fishes, 342, 358, 363
Arteries, 322
Arthrogastra, 189
Arthropoda, 135, 146; classification of, 147
Articulata, 19, 117, 133
Artiodactyla, 511
Ascaris, 127
Ascidia, 225
Ascidiadæ, 230
Ascidians, 230
Asinus, 526
Asiphonida, 253
Asses, 526
Astacidæ, 212
Asteroidea, 108
Astomata (Protozoa), 31
Astræidæ, 83

Ateles, 565
Atoll, 84
Atrial chamber, 228
Atrial system, 237
Auchenia, 518
Auks, 455
Auricle of heart (Vertebrata), 320
Autophagi, 451, 460
Aves, 426 ; general characters of, 426 ; feathers of, 427 ; skeleton of, 430 ; digestive system of, 440 ; respiratory system of, 446 ; nervous system of, 449 ; classification of, 451
Aves erratici, 450
Aves manentes, 450
Aves migratores, 450
Avicularia, 222
Axial elements of skeleton, 306, 307
Axolotl, 372, 383
Aye-Aye, 564

BABOON, 566
Babyrussa Hog, 512
Bactrian Camel, 518
Baculites, 297
Badgers, 540
Balæna, 506
Balænida, 502, 504, 506
Balænoptera, 507
Balancers, 174
Balanidæ, 195, 198
Balanus, 198
Baleen, 502
Balistidæ, 367
Banded Ant-eaters, 492
Bandicoots, 492
Barnacles, 195, 196, 198
Barrier Reefs, 84
Bastard-wing, 429, 437
Batides, 361
Batrachia, 385
Bats, 554, 556, 557, 558
Bears, 539, 540
Bear-animalcule, 188
Beavers, 548
Bees, 178, 179
Bee-parasite, 180
Belemnites, 281, 293
Belemnitidæ, 281, 293
Belly-footed Molluscs, 254
Bicuspid teeth, 476
Bilateral symmetry, 22
Bimana, 568
Binomial system, 27
Biology, 2, 10
Birds. (See *Aves*.)
Bird Lice, 168
Birds of Prey, 466
Birds'-head processes, 222
Bison, 521
Bivalve shells, 234, 241, 242
Blackbirds, 464
Blastoidea, 114
Blattina, 171
Blood-corpuscles of Vertebrata, 318, 319
Boas, 409
Boidæ, 409
Bombyx, 177
Bonasus, 521
Bony Pike, 361, 364
Book Scorpion, 191
Botryllidæ, 230
Botryllus, 231
Bovidæ, 521
Brachiopoda, 219, 233 ; general characters, 234 ; shell of, 234, 235 ; arms of, 236 ; classification of, 238 ; distribution of, 238 ; summary of structure of, 240
Brachyura, 213
Bradypodidæ, 495
Bradypus, 496
Branchial arches or clefts (*Vertebrata*), 304
Branchial arches of Fishes, 344
Branchial ganglion, 217
Branchial hearts (*Cephalopoda*), 284

Branchial sac (*Tunicata*), 227
Branchiata (*Annelida*), 139, 142
Branchiata (*Gasteropoda*), 261
Branchiata (*Vertebrata*), 327
Branchifera, 263
Branchiopoda, 195, 198
Branch-horned Water-Flea, 199
Brevilinguia, 411
Brevipennatæ, 455
Brittle-stars, 109, 111
Bruta, 494
Bubalus, 521
Bubble-shells, 265
Budding, 51, 61, 223
Buccinidæ, 264
Buccinum, 265
Buffalo, 521
Bufonidæ, 386
Bulbus Arteriosus, 342, 358, 363
Bullinidæ, 264
Bustards, 456
Butterflies, 175, 176
"Butterflies of the Sea," 269
Byssus, 248

CACHALOT, 507
Caducibranchiata, 378, 384
Cæca of intestine, 340
Cæciliæ, 381, 382
Caiman, 421
Calamaries, 275, 292
Calice, 81
Calycophoridæ, 68
Calymene, 200
Calyx, 52, 112
Camelidæ, 517
Camelopard, 519
Camelopardalidæ, 519
Camels, 517, 518
Camelus, 518
Canceridæ, 214
Canidæ, 541
Canine teeth, 476
Cape-Badger, 524
Capillaries, 322, 323
Capra, 521
Capreolus, 519
Caprimulgidæ, 465
Capuchin Monkeys, 565
Capybara, 547
Carapace of *Crustacea*, 201, 205 ; of *Chelonia*, 397, 399
Carcharias, 357
Cardiadæ, 253
Carinaria, 265, 266
Carinatæ, 452
Carnivora, 532
Carnivorous (*Gasteropoda*), 256 ; (*Marsupialia*), 492
Carp, 366
Carpus, 315
Carriage-spring apparatus, 236
Cassowary, 456, 458
Castor, 548
Castoridæ, 548
Casuarius, 458
Catarhina, 566
Catodontidæ, 507
Cats, 542
Caudal Vertebræ, 312
Caudal fins, 338
Cave Bear, 540
Cave Hyæna, 542
Cavia, 547
Cavicornia, 520
Cavidæ, 547
Cavies, 547
Cebidæ, 565
Cebus, 565
Cell, 32
Cellulose, 6, 226
Cement, 475
Centipedes, 148, 149
Centrum, 307, 309
Cephalic ganglion, 211
Cephalaspis, 365
Cephalophora, 242, 254
Cephalopoda, 219, 273 ; classification of, 289, 298 ; ink-sac of, 283 ; locomotion of, 278 ; shell of, 275, 279 ; tentacles of, 276 ; palæontology of, 297

Cephalothorax, 148, 182, 194
Ceratites, 296
Cercariæ, 126
Cercolabes, 548
Cercoleptes, 540
Cerebral ganglion, 217, 251, 262
Cerebrum, 325, 480
Cerebellum, 325, 480
Cerebro-spinal nervous axis, 302, 325
Certhidæ, 464
Cervical vertebræ, 312, 470
Cervidæ, 518
Cervus, 519
Cestracion, 360
Cestraphori, 360
Cestum veneris, 92, 93, 95
Cetacea, 501
Cetiosaurus, 421
Chaillu, 568
Chain-Salpa, 232
Chameleon, 414
Chamæleontidæ, 414
Chamois, 520
Cheiromydæ, 564
Cheiromys, 564
Cheiroptera, 554
Cheirotherium, 388
Chelæ, 190
Chelicerræ, 190
Chelifer, 191
Chelonia, 397; endoskeleton of, 401; carapace of, 397; classification of, 402
Chelone, 403
Chilognatha, 149
Chilopoda, 149
Chimera, 360
Chimpanzee, 567
Chirotes, 412
Chitons, 254, 264
Chitonidæ, 264
Chlorophyll, 6
Chorda dorsalis. (See Notochord.)
Chromotophora, 276, 415
Chrysalis, 162
Chrysochlorus, 552
Chylaqueous fluid, 138
Chyle, 317, 318
Chylific stomach, 159
Chyme, 316
Cicada, 169
Ciconinæ, 456
Cidaris, 108
Cilia, 5, 31, 44, 47, 56
Ciliata, 51
Circulation in sponges, 43
Circulation in Vertebrata, 320
Cirrhus, 137, 196, 236
Cirripedia, 195
Cirrostomi, 349, 351
Civets, 543
Clam-shells, 253
Claspers of Fishes, 359
Class, 24, 26
Classification, system of, 23
Clavellinidæ, 230
Clavicle, 314
Cleft-tongued Lizards, 411
Cleodora, 272
Clio, 271, 272
Clitellum, 141
Cloaca, 159, 160, 184, 325, 369, 394, 444, 484
Clothes-moth, 177
Clupeidæ, 366
Clypeastridæ, 108
Cnidæ, 56, 59
Coati, 540
Cobra di Capello, 410
Coccus, 169
Coccyx, 471
Cochineal insect, 169
Cockles, 253
Cockroaches, 171
Cod, 366
Cœlenterata, 17, 18, 55; characters of, 18, 55; classification of, 57, 95
Cœnenchyma, 81, 82
Cœnœcium, 220
Cœnosarc, 66, 68

Coleoptera, 180
Collar of Mollusca, 256
Colobus, 566
Colonial nervous system, 223
Coluber, 409
Colossochelys, 403
Colubrina, 407, 409
Columba, 460
Columbacei, 460
Columbidæ, 460
Columella, 81, 255
Colymbidæ, 455
Comatula, 112, 114
Complementary males, 197
Complete metamorphosis, 162, 174
Compound Ascidians, 230
Compsognathus, 423
Conchifera, 242
Condyles, 371, 374, 469
Conirostres, 464
Contractile vesicles, 36, 49
Cone shells, 264
Coney, 522, 523
Conidæ, 264
Conical appendages of *Pteropoda*, 269, 270
Coots, 456
Coracoid bones, 314
Corrallite, 81
Corallium, 91
Corallum, 79
Coral, 79
Coral reefs, 83; formation of, 84
Cordylophora, 63, 67
Corpus callosum, 480, 491
Correlation function of, 10, 12
Cortical layer, 47
Corvidæ, 464
Corynida, 67; development of, 63
Coturnix, 460
Coypu, 549
Cowries, 264
Cows'-paps, 88
Crabs, 213, 214
Cranes, 456
Crane-Flies, 175
Crangonidæ, 212
Crania, 238
Craniadæ, 238
Craspeda, 77
Cray-fish, 212
Creepers, 464
Cricket, 171
Crinoidea, 111
Cristatella, 224
Crocodilia, 397, 416; classification of, 420
Crocodiles, 420
Crocodilus, 420, 421
Crop of *Insecta*, 158; of Birds, 442
Crotalidæ, 408
Crown-animalcule, 130
Crows, 464
Crustacea, 147, 148, 194; classification of, 195; shell of, 195
Ctenocyst, 94
Ctenoid scales, 332
Ctenophora, 92
Ctenophoral canals, 94
Ctenophores, 92, 93
Cuckoo, 462
Cuculidæ, 462
Culicidæ, 174
Cursores, 453, 456
Cursorial *Orthoptera*, 171
Cuticle of *Infusoria*, 47
Cuttle-Bone, 275, 280
Cuttle-Fishes. (See *Cephalopoda*.)
Cyclical change, 3
Cycloid scales, 331
Cyclolabridæ, 367
Cyclops, 195, 198
Cyclostomi, 353
Cyclostomidæ, 267
Cydippe, 95
Cynipidæ, 178
Cynocephalus, 566
Cynomorpha, 566
Cynthia, 230

Cypræidæ, 264
Cyprinidæ, 366
Cypselidæ, 465
Cyst, 33
Cystic Worms, 123, 125
Cysticercus, 125
Cystoidea, 114

Dama, 519
Daphnia, 195, 199
Darwin's theory of Coral Reefs, 84
Dasypodidæ, 495, 496
Dasyures, 492
Dasyuridæ, 492
"Dead-man's finger" polype, 88
Death's-head Moth, 175
De Blainville, 480
Decapoda, 195, 205; classification of, 212
Decapoda (*Cephalopoda*), 290, 292
Deer, 518
Delphinidæ, 508
Delphinus, 508
Demodex, 188
Dental formula, 477, 78
Dentalidæ, 264
Dentine, 474
Dentirostres, 464
Development, 10, 11
Dextral shells, 255
Diaphragm, 262, 469, 479
Diapophyses, 309
Diastema, 546, 561, 569
Dibranchiata, 289, 290
Dicotyles, 512
Dicynodontia, 423
Didelphia, 490
Didelphidæ, 492
Didelphys, 492
Dididæ, 460
Didymograpsus, 74
Difference between Animals and Plants, 5
Differences between Organic and Inorganic bodies, 2
Difflugia, 37
Digitigrada, 535, 541
Dimyaria, 245
Dinornis, 458
Dinotherium, 529
Diphyes, 69
Diphyodont Mammalia, 474
Diplograpsus, 74
Dipnoi, 349, 367
Dipodidæ, 549
Diptera, 174
Dipterus, 364, 365
Dipus, 549
Discophora (Annelida), 139
Dissepiments, 81
Distal, 58
Distoma, 125; development of, 126
Distribution, 10, 13
Diurnal (*Lepidoptera*), 176; (*Raptores*), 466
Divers, 455
Divisions of Natural Science, 1; Biological Science, 10
Dodo, 460, 461
Dogs, 541
Dog-Fishes, 361
Dolphins, 508
Doridæ, 265
Doris, 265
Dormice, 549, 550
Dorsal fins of Fishes, 338
Dorsal oar, 137
Dorsal Vertebræ, 312
Doves, 460
Down, 428
Draco Volans, 413, 425
Dragon-Flies, 172
Dromaius, 458
Dromedary, 518
Drones, 179
Duck-billed Water-Mole, 484
Ducks, 453, 455
Dugong, 500
Dynastes Hercules, 181
Dytiscus, 181

EAGLES, 466
Earthworm, 136
Earwigs, 171
Ecderon, 80
Ecdysis, 163
Echidna, 485, 487
Echinodermata, 98; classification of, 108
Echinoidea, 108
Echinorhynchus, 127, 128
Echinozoa, 18, 97, 98; classification of, 98, 131
Echinus, 98, 100, 103, 108
Ecthoræum, 59
Ectocyst, 220
Ectoderm, 56
Edentata, 494
Edriophthalmia, 202, 203
Eels, 366
Ehrenberg's experiments, 35, 49
Elasmobranchii, 349, 356
Element of form, 22
Electrical organs of Fishes, 347
Elephants, 529
Elephas, 529
Elk, 519
Elytra, 157, 171, 180
Emeu, 456, 458
Emydea, 402
Enamel, 475
Encephala, 242
Encephalon, 325
Encrinites, 114
Endocyst, 221
Endoderm, 56, 221
Endopodite, 207
Endoskeleton, 306, 307, 333, 373, 430, 470
Entomophagous Edentata, 495, 496
Entomostraca, 195, 198
Entozoa, 117
Eozoon, 41
Epeira, 192
Ephemeridæ, 172
Ephyra, 73, 74
Epipodite, 208, 209
Epistome, 224
Equidæ, 526
Equus, 526
Equivalve shells, 242
Erethizon, 548
Erinaceidæ, 552
Erinaceus, 552
Ermine, 544
Errantia, 139, 143
Esocidæ, 366
Euelephas, 529
Eureta, 402
Eurypterida, 202
Eurypterus, 202
Evagination, 221
Exhalent syphon, 251
Exopodite, 206
Exoskeleton (of *Crustacea*), 146, 205; (of *Vertebrata*), 306, 397, 416
Eyes of *Insecta*, 152

FALCONIDÆ, 466
Falcons, 466
False molars, 476
Fallow Deer, 519
Family, 24, 26
Feathers, 427
Feather star, 112
Felidæ, 541
Femur, 156, 315
Fiber, 548
Fibula, 315
Filaria, 127
File Fishes, 367
Finches, 464
Finner-Whales, 507
Fishes. (See Pisces.)
Fissilinguia, 411
Fission, 37, 50
Fissirostres, 465
Flabella, 210
Flagellata, 51, 52
Flat Fishes, 330, 366
Fleas, 174

Flies, 174
Flukes, 125
Flustra, 6, 15, 219, 220, 224
Fly-catchers, 464
Flying-Dragon, 413, 425
Flying-Lemur, 551, 553
Flying-Squirrel, 550
Food of animals and plants, 7
Food vacuoles, 36, 49
Foot (of Mollusca), 248, 254, 256
Foot-jaws (of Crustacea), 208
Foot-tubercles, 137
Foraminifera, 38 ; shell of, 38, 39
Forficulina, 171
Formicidæ, 178
Fowls, 460
Foxes, 541
Fox-Bats, 556
Fraterculidæ, 455
Fresh Water Mussels, 253
Fresh Water Shrimp, 204
Fringing-Reef, 84
Frigate-Bird, 455
Fringillidæ, 464
Frogs, 386 ; metamorphosis of, 379
Fulcra, 362
Fulica, 456
Function, specialisation of, 14
Funiculus, 223
Funnel of Cephalopoda, 273, 278, 283
Furculum, 435, 485
Furrowed Whales, 507

GADIDÆ, 366
Galeopithecus, 551, 553
Galeopithecidæ, 551, 553
Gallinacei, 458, 460
Gall-flies, 178, 179
Gallus, 460
Gammarus, 204
Ganglion, 94, 105, 134, 211, 217
Ganglionic nervous system of Vertebrata, 302, 325
Ganoid scales, 332
Ganoidei, 349, 361
Gapers, 253
Garden-Spider, 192
Gasteropoda, 219, 254 ; shell of, 254 ; tongue of, 258 ; classification of, 263
Gastric juice, 316
Gavial, 420
Gavialis, 420
Gecarcinidæ, 214
Geckos, 413
Geckotidæ, 413
Geese, 455
Gemmation, 51, 61, 223
Gemmules, 45
Generation, spontaneous, 46
Generations, alternation of, 64, 72, 232
Genette, 543
Genus, 25
Geocores, 170
Geographical distribution, 10, 13
Geological distribution, 10, 13
Gephyrea, 136
Germ theory, 46, 47
Germs, 5, 47
Gibbon, 567
Giraffe, 519
Gizzard (of *Insecta*), 158 ; (of *Aves*), 442, 443
Gladius, 280
Glass Zoophytes, 87
Globe-Fishes, 367
Glutton, 541
Glyptodon, 499
Gnats, 174
Goats, 520, 521
Goat-Suckers, 465
Golden Mole, 552
Goniatites, 296
Gonophores, 62
Gonosome, 66
Gordiacea, 128
Gordius, 127, 128
Gorgonia, 91
Gorgonidæ, 83, 91

Gorilla, 567
Gouridæ, 460
Gosse, 248
Grallatores, 453, 455
Graptolidæ, 74
Graptolites, 74
Grasshoppers, 171
Great Seal, 539
Grebe, 454
Greenland Whale, 506
Gregarina, 31, 32; development of, 32
Gregarinida, 31
Green Lizard, 412
Green Turtle, 403
Ground-Pigeons, 460
Grouse, 460
Gruidæ, 456
Gryllina, 171
Guard of *Belemnitic* shell, 281
Guinea-Pig, 547
Guinea-Worm, 127
Gulls, 453, 455
Gulo, 541
Gymnodontidæ, 367
Gymnolæmata, 224
Gymnotus, 366
Gymnophiona, 381
Gymnosomata, 272

HÆMAL arches of Vertebrata, 308
Hæmal flexure of Intestine, 228, 259, 263
Hæmapophyses, 308
Hæmal spines, 308
Hæmopsis, 141
Hag-fishes, 353
Hairs, 470
Hair-worms, 127, 128
Halicore, 500
Halteres, 157, 174
Hanno, 568
Hapalidæ, 565
Hares, 547
Harmless Snakes, 409
Harp Seal, 539
Harvest Spiders, 191
Hawks, 466
Hawk's bill Turtle, 403
Head-footed Molluscs, 273
Hectocotylus, 287, 288, 292
Hedgehog, 552
Helicidæ, 267
Hemimetabola, 162, 165, 169
Hemiptera, 169
Hercules Beetle, 181
Hermit Crabs, 212
Herons, 456
Herpestes, 543
Heterocercal tails, 339
Heterogangliata, 217
Heterogeny, 46
Heterophagi, 451
Heteropoda, 263, 265
Heteroptera, 169, 170
Hippocampidæ, 367
Hippocrepia, 224
Hippopotamidæ, 512
Hippopotamus, 512
Hirudinea, 139
Hirudo, 139
Hirundinidæ, 465
Hog, 512
Holocephali, 360
Holometabola, 162
Holostomata, 264
Holostomatous shells, 256
Holothuria, 115
Holothuroidea, 115
Homalopsidæ, 409
Homarus, 195
Homo, 568
Homocercal tails, 339
Homogangliata, 135
Homology, 21
Homology of vertebral column, 308, 309, 310, 311
Homoptera, 169
Honey-comb stomach, 515
Honey-eating Badger, 541
Hooded Snake, 410
Hoopoes, 464

Horses, 526
Horse-shoe Bats, 558
Howling Monkeys, 565
Humerus, 314
Humming-Birds, 464
Huxley, 30, 223, 229, 327, 371, 400
Hyæna, 542
Hyænidæ, 542
Hyalæa, 270, 272
Hyalonemadæ, 87
Hydatina, 130
Hydra, 15, 58, 59, 67
Hydra tuba, 72
Hydridæ, 67
Hydrochærus, 547
Hydrocores, 170
Hydrophidæ, 410
Hydrorhiza, 60, 66
Hydrosoma, 66
Hydrothecæ, 66, 68
Hydrozoa, 57; reproduction of, 61, 62, 63; classification of, 65, 66, 95
Hylides, 386
Hylobates, 567
Hymenoptera, 177
Hyracoidea, 522
Hyrax, 522, 523, 524
Hystricidæ, 547
Hystrix, 548

IBISES, 456
Ichneumon, 543
Ichthyodorulites, 360
Ichthyomorpha, 382
Ichthyopsida, 328, 329, 370
Ichthyosauria, 422
Ideal typical vertebra, 309
Iguana, 413
Iguanidæ, 413
Iguanodon, 423
Imago, 162, 164
Implacentalia, 481, 483
Incisor teeth, 476
Incomplete metamorphosis, 165, 169
Individual, 65, 232
Infra-œsophageal ganglion, 211, 217
Infundibulum, 93, 273, 283
Infundibulata, 224
Infusoria, 31, 45; classification of, 51; reproduction of, 50
Inia, 509
Ink-sac of Cephalopoda, 283
Ingluvies, 158, 442
Innervation, function of, 10, 12
Innocua, 409
Innominate bone, 315
Inoperculata, 267
Inorganic bodies, 2; form of, 2; chemical composition of, 2; structure of, 2; mode of increase of, 2; cyclical change of, 3
Inorganic series, 2
Insecta, 147, 150; digestive system of, 158; nervous system of, 161; metamorphosis of, 162; respiratory system of, 160; classification of, 167
Insectivora, 551
Insessores, 453, 462
Integro-pallialia, 247, 253
Inter-ambulacral areas, 100
Interspinous bones of Fishes, 335
Irish Elk, 519
Irritability, function of, 10, 12
Isis, 82, 90, 91
Isopoda, 195, 202
Iulidæ, 148, 149
Iulus, 149
Ixodes, 189

JACKALS, 541
Jaws of Vertebrata, 305
Jays, 464
Jelly-Fishes, 70
Jerboas, 549
Jones, Rhymer, 25

KANGAROO, 488, 492

Keratode, 42
Kidneys, 324
King-Crabs, 195, 201
Kingfishers, 465
"King of the Herrings," 360
Kinkajous, 540
Kites, 466

LABIAL palpi, 153
Labium, 153, 154, 208
Labrum, 153, 154, 208
Labyrinthodontia, 381, 387
Lacerta, 412
Lacertidæ, 412
Lacertilia, 397, 410; characters of, 410; classification of, 412
Lacteal system, 318
Lagena, 40
Lagoon-reefs, 84
Lagopus, 460
Lamellibranchiata, 219, 242; shell of, 242; classification of, 252
Lamprey, 333, 353, 356
Lamp-shells, 236
Lancelet, 306, 320, 333, 349, 350
Land-bugs, 170
Land-crabs, 214
Land-Newts, 384, 385
Land-Salamanders, 385
Lantern of Aristotle, 104
Laniidæ, 464
Laridæ, 453, 455
Larks, 464
Larva, 162, 163, 164
Lateral lines of Fishes, 347
Leaf-rolling Caterpillar, 177
Leathery Turtle, 403
Leeches, 141
Lemmings, 549
Lemurs, 562, 563
Lemuridæ, 562, 563
Lemuroidea, 562
Leopard, 542
Lepadidæ, 195, 198
Lepas, 195, 198
Lepidoganoidei, 364
Lepidoptera, 175
Lepidosiren, 367
Lepidosteus, 332, 361, 363, 364
Leporidæ, 547
Leptocardia. (See Pharyngobranchii.)
Lepus, 547
Libellula, 172
Libellulidæ, 172, 173
Lice, 168
Life, nature of, 3, 4, 5; physical basis of, 3, 30; definitions of, 4
Ligamentum nuchæ, 471
Lily-Stars, 114
Limacidæ, 267
Limbs of Vertebrata, 304, 314
Limnæidæ, 267
Limpet, 264
Limulus, 195, 201
Ling, 338, 366
Lingual ribbon of *Gasteropoda*, 258
Linguatula, 187
Linguatulina, 187
Lingula, 239
Lingulidæ, 239
Linnets, 464
Lion, 541
Littorina, 257
Littorinidæ, 264
Liver-fluke, 125
Lizards, 410, 412
Llamas, 518
Lobster, 195, 205, 212
Lob-worm, 144, 145
Locust, 171
Locustina, 171
Locust Shrimp, 195, 204
Loggerhead Turtle, 403
Loligo, 275
Longipennatæ, 455
Lophobranchii, 367
Lophophore, 221
Loricata (*Reptilia*), 391; (*Edentata*), 496

Lories, 564
Loosook, 509
Loxodon, 529
Lucernaria, 70, 71
Lucernaridæ, 70, 71
Lumbar vertebræ, 312
Lumbricus, 136, 141
Lutra, 544

Macacus, 566
Macaques, 566
Mackerel, 367
Macrobiotus, 188
Macropodidæ, 492
Macrospondylus, 421
Macrura, 212
Madreporidæ, 83
Madreporiform tubercle, 100, 105
Maggots, 175
Magpies, 464
Maidæ, 214
Malacodermata, 78
Malacopteri, 366
Mallophaga, 168
Mammalia, 328; general characters of, 468, 469; blood-corpuscles of, 318, 319; teeth of, 474; circulation in, 320; skeleton of, 470, 471, 473; digestive system of, 473; nervous system of, 479; reproduction of, 480; classification of, 480, 482, 572
Mammary glands, 468
Mammoth, 530
Man, 562, 568; anatomical characteristics of, 568, 569; brain of, 569; palæontology of, 570
Man-like Apes, 567
Manatee, 500
Manatus, 500
Mandibles, 153, 154
Manidæ, 498
Mandrills, 567
Mantle of *Mollusca*, 216; of *Tunicata*, 226; of *Brachiopoda*, 235; of *Lamellibranchiata*, 245; of *Gasteropoda*, 255; of *Cephalopoda*, 273, 279
Manyplies, 515
Mare's Tail coral, 82, 91
Marginal plates of *Chelonia*, 400
Marmosets, 565
Marmots, 550
Marsipobranchii, 349, 353
Marsh-Tortoises, 402
Marsupial bones, 486, 489
Marsupialia, 487; classification of, 492
Marsupium, 486, 488, 489
Mason-spiders, 192
Mastodon, 531
Maxillæ, 153, 154
Maxillary palpi, 153, 183
Maxillipedes, 208
May-flies, 172, 173
Meandrina, 83
Median fins of Fishes, 336, 338
Medusidæ, 70
Megaceros, 519
Megalopa, 212
Megalosaurus, 423
Megaptera, 507
Megatherium, 499
Meleagris, 460
Meles, 541
Melidæ, 540
Mellivora, 541
Menobranchus, 384
Menopoma, 384
Mephitis, 544
Merosome, 22
Merostomata, 201
Merulidæ, 464
Mesenteries of Actinozoa, 57, 76
Mesothorax, 150, 156
Metacarpus, 315
Metamorphosis of *Amphibia*, 379; of *Insecta*, 162; of *Crustacea*, 211

Metatarsus, 315
Metathorax, 150, 157
Mice, 549
Microlestes, 493
Migration of Birds, 450
Milk-teeth, 474
Millipedes, 148, 149
Mites, 188
Molar teeth, 476
Moles, 551
Mollusca, 19, 216; general characters of, 216, 217; shell of, 216, 241, 242; classification of, 218, 298
Mollusca proper, 218, 241; classification of, 242
Molluscoida, 218, 219; classification of, 218
Monitors, 413
Monkeys, 560
Monodelphia, 572
Monodon, 508
Monomyaria, 245
Monophyodont Mammalia, 474
Monothalamia, 39
Monotremata, 483
Morphological types, 14, 17
Morphology, 10, 11, 12
Morse, 537
Moschidæ, 518
Moschus, 319, 518
Moths, 175, 176
Mouths of *Insecta*, 152
Mud-fish, 367, 368
Mud-tortoises, 402
Mugilidæ, 367
Mullet, 367
Multivalve shells, 196, 241, 254
Multungula, 522
Murænidæ, 366
Muricidæ, 264
Muridæ, 549
Mus, 549
Muscicapidæ, 464
Muscidæ, 174
Musk-deer, 319, 518
Mussels, 253
Musquash, 548
Mustela, 544
Mustelidæ, 543
Myacidæ, 253
Mycetes, 565
Myelon, 325
Mygale, 192
Mylodon, 499
Myodes, 549
Myopotamus, 549
Myoxidæ, 549
Myoxus, 550
Myriapoda, 147, 148
Myrmecobiidæ, 492
Myrmecophagidæ, 495, 496, 497
Mytilidæ, 253
Myxine, 353, 356
Myxinidæ, 353

Naididæ, 142
Naja, 410
Naked-gilled *Gasteropoda*, 265
Narwhal, 508
Nasua, 540
Natal callosities, 565, 566, 567
Natatores, 453
Nautilidæ, 295
Nautilus, 275, 279, 293, 295; shell of, 279, 294
Nectocalyx, 68, 69, 70
Nematelmia, 118, 127
Nematoda, 127
Nemertes, 127
Nemertida, 127
Nereida, 145
Nereis, 145
Nervures, 156, 161, 171, 177
Neural arches of *Vertebrata*, 307, 309
Neural canal, 307
Neural flexure of intestine, 223, 249, 259, 263
Neural plates of *Chelonia*, 399
Neural spine, 307, 309

Neural tube of *Vertebrata*, 302
Neurapophyses, 307
Neuropodium, 137
Neuroptera, 171
Neuters, 179
Newts, 384
Nictitating membrane, 395, 449
Nidamental capsules, 263 ; glands, 287
Noctiluca, 58
Nocturnal *Lepidoptera*, 176
Nocturnal *Raptores*, 466
Non-Ruminantia, 511
Notochord, 303, 333, 351
Notonecta, 170
Notopodium, 137
Nucleobranchiata, 263, 265
Nucleolus, 32, 49
Nucleus, 32, 48, 49, 319
Nudibranchiata, 265
Nummulites, 41
Nutrition, function of, 10, 12
Nycticebidæ, 564

OCELLI, 71, 152, 186
Octopoda, 290
Octopodidæ, 290
Octopus, 274, 290
Odontophora, 242
Odontophore, 258, 270, 286
Œsophagus, 316
Oken, 309
Oligochætæ, 139, 141
Omnivora, 511
Oniscidæ, 203
Oniscus, 195, 203
Operculata, 267
Operculum of *Gastéropoda*, 257, 267 ; of Fishes, 336, 344
Ophidia, 397, 403
Ophiocoma, 111
Ophiomorpha, 381
Ophiura, 111
Ophiuroidea, 109, 111
Opisthobranchiata, 263, 264
Opisthocœlia, 421
Opisthocœlous vertebræ, 335, 361, 373, 392, 417
Opossums, 488, 492
Orang-outang, 567
Orbicularis panniculi, 552
Order, 24, 26
Organic bodies, 2 ; form of, 2 , chemical composition of, 2 ; intimate structure of, 2 ; mode of increase of, 2 ; cyclical or periodic change of, 3
Organic series, 2
Organisation, 4
Organ-pipe coral, 82, 90
Ornithodelphia, 484
Ornithorhynchus, 484, 486
Ornithoscelida, 422, 423
Orthoceras, 295, 296
Orthoptera, 171
Orycteropidæ, 498
Orycteropus, 498
Os quadratum, 390, 393, 405, 432, 473
Oscula, 43
Ostraciontidæ, 367
Ostrea, 247
Ostræidæ, 253
Ostrich, 456, 457, 458
Otaridæ, 536
Otaria, 537
Otidæ, 456
Otoliths, 262, 286, 346
Otolitic vesicles, 71
Otter, 544
Ovidæ, 520
Oviparous reproduction, 326, 348, 396, 449
Ovipositor, 158
Ovis, 521
Ovo-viviparous reproduction, 327, 396
Owen, 135, 217, 309, 400, 480
Owls, 466
Oxen, 521
Oxyuris, 127

Pachydermata, 510
Paddlefish, 365
Paguridæ, 212
Paired fins of Fishes, 336
Palæotherium, 525
Pali, 81
Pallial line, 246
Pallial sinus, 246
Palliobranchiata, 237
Pallium. (See Mantle.)
Palmipedes, 453
Palpi (*Insecta*), 153; (*Arachnidæ*), 183; (*Mollusca*), 249
Pancreas, 317
Pangolin, 498
Panspermists, 46
Panthers, 542
Pantopoda, 187
Paper Nautilus, 275, 279, 290
Papio, 567
Paragastric canals, 94
Paramæcium, 47, 51
Parapodia, 137
Parapophyses, 309
Parieto-splanchnic ganglion, 217, 251
Parrots, 462
Partridges, 460
Passeres, 462
Patagium, 423, 553, 555, 556
Patellidæ, 264
Paunch, 515
Pearly Nautilus, 275, 279, 293
Peccary, 512
Pecten, 253
Pectoral fins of Fishes, 336
Pectoral limb, 315
Pedal ganglion, 217, 251
Pedicellariæ, 102, 103
Pediculus, 168
Pedipalpi, 189
Peduncle, 196
Pelias, 408
Pelicans, 455
Pelicanidæ, 455
Pelvic limb, 315
Pelvis, 312, 315
Pen of *Cephalopoda*, 275, 280
Penguins, 453, 455
Pennatula, 89
Pennatulidæ, 89
Pentacrinus, 114
Pentastoma, 187
Pentastomida, 187
Peramelidæ, 492
Peranema, 51, 53
Perchers, 462
Perches, 367
Percidæ, 367
Perdix, 460
Perennibranchiata, 377, 382
Pericardium, 479
Perisome, 98
Perissodactyla, 510, 521
Peristome, 256
Perivisceral fluid, 223; space, 138
Periwinkle, 264
Petromyzon, 353, 356
Petromyzonidæ, 353
Phalangers, 492
Phalanges, 315
Phalangidæ, 191
Phalangistidæ, 492
Pharyngobranchii, 349
Pharyngognathi, 367
Pharynx of Ascidians, 227
Phascolomydæ, 492
Phasianidæ, 460
Phasianus, 460
Pheasant, 460
Philopteri, 168
Phoca, 538, 539
Phocæna, 508
Phocidæ, 538
Pholadidæ, 253
Pholas, 251, 253
Phosphorescence of the sea, 53, 71
Phragmocone, 281
Phylactolæmata, 224
Phyllophaga, 178
Phyllostoma, 558

Phyllostomidæ, 558
Physalia, 69, 70
Physeter, 507
Physeteridæ, 507
Physical basis of life, 3
Physiology, 10, 11, 12
Physiological division of labour, 16
Physophoridæ, 69
Phytophaga (*Gasteropoda*), 256; (*Marsupialia*), 492; (*Edentata*), 495
Picidæ, 462
Pigeons, 460
Pigment spots, 71
Pikes, 366
Pinna, 248, 252
Pinnigrada, 534, 535
Pinnipedia, 534, 535
Pipa, 386
Pipe-fishes, 367
Pipidæ, 386
Pisces, 329; scales of, 331; endoskeleton of, 333; fins of, 336; digestive system of, 339; classification of, 349; reproduction of, 348; nervous system of, 346; respiration of, 344; circulation in, 342; swimming-bladder of, 344
Pithecus, 567
Placenta, 360, 480
Placentalia, 482, 494
Placoganoidei, 364
Placoid scales, 332
Plagiostomi, 360
Planarida, 127
Plant-eating *Edentata*, 495
Plant-eating *Gasteropoda*, 256
Plant Lice, 169
Plantigrada, 535, 539
Planula, 72
Plastron, 398, 400
Platanista, 509
Platinistidæ, 509
Platyelmia, 118
Platyrhina, 565
Plecotus, 557
Plectognathi, 367
Plesiosauria, 422
Plesiosaurus, 422
Pleurapophyses, 308
Pleuron, 205
Pleurobrachia, 93, 95
Pleuronectidæ, 366
Ploughshare-bone, 432, 467
Plumatella, 224
Plumule, 428
Pluteus, 108
Pneumatic bones, 423, 430, 431
Pneumatic duct, 363, 364
Pneumatophore, 69
Podicipina, 454
Podocyrtis, 40
Podophthalmia, 204
Podura, 168
Pœcilopoda, 195, 201
Poisers, 157, 174
Poison-gland of Arachnida, 183; of Ophidia, 406
Polecat, 544
Polian vesicles, 105, 106
Polygastrica, 50
Polype, 58, 61, 65
Polypide, 220
Polypite, 66, 68, 70
Polypterus, 361, 364
Polythalamia, 39
Polyzoa, 218, 219; digestive system of, 222; reproduction of, 223; classification of, 224
Polyzoarium, 219
Pond-snails, 267
Porcupine, 547, 548
Pores of sponge, 43
Porpoise, 508
Port-Jackson Shark, 360
Portal system of veins, 343
Portuguese Man-of-war, 69
Pottos, 564
Poulpes (*Cephalopoda*), 290
Præmolar teeth, 476

Prawns, 212
Primates, 562
Primitive groove, 303
Pristis, 361
Proboscidea, 526
Proboscis (of *Insecta*), 154; (of Elephant), 526, 527
Procœlia, 420
Procœlous vertebræ, 373, 392, 416, 417
Procyon, 540
Productus, 240
Productidæ, 240
Proglottis, 120, 122
Prolegs, 177
Pro-ostracum, 281
Propodite, 206
Proscolex, 123, 124
Prosimiæ, 563
Prosobranchiata, 263, 264
Proteidæ, 382
Proteus, 372, 382
Prothorax, 150, 155
Protoplasm, 3, 14, 17, 30
Protopodite, 206
Protopteri, 367
Protozoa, 17, 18; general characters of, 29, 30; classification of, 31, 54
Proventriculus, 442, 443
Proximal, 58
Psalterium, 515
Pseudo-hæmal system, 138
Pseudonavicellæ, 34
Pseudopodia, 31, 34, 35
Psittacidæ, 462
Psittacus, 462
Ptarmigan, 460
Pterichthys, 365
Pterodactyls, 418, 423
Pteromys, 550
Pterygotus, 202
Pteropidæ, 556
Pteropoda, 219, 268; classification of, 272
Pteropus, 557
Pterosauria, 422, 423
Puffins, 455
Pulicidæ, 174
Pulmogasteropoda. (See *Pulmonifera*.)
Pulmonaria, 186, 189
Pulmonary sacs, 182
Pulmonifera, 263, 267
Pupa, 162, 164
Pupa case, 177
Purpura, 257
Pycnogonum, 187
Pycnogonida, 187
Pygostyle, 432, 467
Pyloric appendages of Fishes, 340
Pyrosoma, 230, 233
Pyrosomidæ, 230, 233
Pythons, 409

QUADRATE bone, 390, 393, 405, 432, 473
Quadrumana, 560
Quagga, 526
Quails, 460
Quill feathers, 428

RABBIT, 547
Racoon, 540
Radial canals, 94
Radial symmetry, 22
Radiata, 55, 97
Radiolaria, 40
Radius, 315
Raiidæ, 361
Rails, 456
Rallidæ, 456
Rana, 386
Ranidæ, 386
Raptores, 453, 466
Rasores, 453, 458
Rats, 549
Ratitæ, 452, 456, 457
Rattlesnakes, 408, 409
Rays, 361
Razor-shells, 248, 251, 253
Rectrices, 429

Red-coral, 82, 91
Red Deer, 519
Regnum Protisticum, 7
Rein Deer, 519
Rennet, 516
Reproduction, function of, 10, 12
Reptilia, 391; characters of, 391; circulation of, 394; classification of, 397
Resting larva, 123
Reticulum, 515
Reverse shells, 255
Rhamphastidæ, 462
Rhea, 458
Rhinocerotidæ, 522
Rhinoceros, 522, 523
Rhinolophidæ, 558
Rhinolophus, 558
Rhizopoda, 31, 34; classification of, 37
Rhizostomidæ, 72
Rhytina, 500
Ribbon Worms, 127
Ribs, 308, 312
Right Whale, 506
Rodentia, 544
Roebuck, 519
Rorqual, 507
Rostrum, 188, 205
Rot in Sheep, 126
Rotifera, 98, 117, 118, 129
Round Worms, 127
Rugosa, 92
Rumen, 515
Ruminantia, 513
Rumination, 514, 516
Rupicapra, 520

SABLE MARTEN, 544
Sacral vertebræ, 312
Sacrum, 312
Salamanders, 384, 385
Salamandridæ, 384, 385
Salivary glands, 316
Salmon, 366
Salmonidæ, 366
Salpa, 230, 231
Salpadæ, 230, 231; development of, 232
Saltatorial *Orthoptera*, 171
Sand-canal, 105
Sandhoppers, 195, 204
Sand-lances, 366
Sand Lizards, 412
Sand-stars, 111
Sanguisuga, 141
Sarcode, 3, 30
Sarcoptes, 188
Sauropsida, 328, 389, 426
Saururæ, 453, 466
Saw Fish, 361
Saw Flies, 178, 179
Scales of Fishes, 331
Scaly Lizard, 412
Scale-winged *Insecta*, 175
Scansores, 453, 461
Scaphognathite, 208, 210
Scaphites, 297
Scapula, 314
Scincidæ, 412
Scincus, 412
Sciuridæ, 550
Sclerobasica, 87
Sclerobasic coral, 79, 82
Sclerodermata, 79
Sclerodermic coral, 79, 80
Sclerotic plates, 422, 449
Scolecida, 98, 117; classification of, 118
Scolex, 123, 124
Scolopacidæ, 456
Scolopendra, 148, 149
Scolopendridæ, 148, 149
Scomberidæ, 367
Scorpions, 189
Scorpionidæ, 189
Scutes, 391, 416
Scyphistoma, 73
Sea-acorns, 195, 198
Sea-anemones, 75, 78
Sea-blubbers, 70
Sea-Bears, 537

Sea-Cows, 500
Sea-cucumbers, 115
Sea-grapes, 287
Sea-Hares, 264
Sea-Horses, 367
Sea-lemons, 265
Sea-Lions, 537
Sea-Mats, 219, 224
Sea-Mice, 145
Sea-pens, 89
Sea-rods, 90
Sea-Slugs, 265
Sea-Squirts, 225, 226, 230
Sea-Unicorn, 508
Seals, 536, 538
Selachii, 361
Semi-plantigrada, 542
Semnopithecus, 566
Sepia, 275, 293
Sepiadæ, 293
Sepiostaire, 275, 280
Septa, 81, 279, 281, 290, 294, 295, 297
Serial homology, 21, 133, 205
Serpula, 142, 143
Sertularidæ, 62, 67, 68, 69
Sessile-eyed *Crustacea*, 203
Setæ, 137
Sharks, 356, 361
Sheep, 520
Shell, 216, 241 ; of *Brachiopoda*, 234 ; of *Gasteropoda*, 254 ; of *Cephalopoda*, 279 ; of *Lamellibranchiata*, 242 ; of *Pteropoda*, 269 ; of *Echinozoa*, 99 ; of *Crustacea*, 195
Short-tongued Lizards, 411
Shoulder-blade, 314 ; girdle, 314
Shrew-mice, 552
Shrikes, 464
Shrimps, 212
Siamang, 567
Silk Moth, 177
Simiæ, 563
Simiadæ, 562
Sinistral shells, 255
Sinu-pallialia, 247, 253
Sinuses, 210
Siphonida, 253
Siphonostomata, 256, 264
Siphons, 246, 261
Sipuncle, 290, 294, 295, 297
Sipunculus, 136
Sipunculoidea, 136
Siredon, 383
Siren, 372, 382,.384
Sirenia, 499
Sirenidæ, 382
Sirex, 179
Skates, 361
Skeleton of Vertebrata, 305
Skinks, 412
Skunks, 544
Sloth-animalcules, 188
Sloths, 495, 496
Slow-worms, 412
Slugs, 267
Smooth Newt, 385
Smooth Whales, 507
Snails, 267
Snakes, 403
Snipes, 456
Social *Ascidians*, 230
Soft-Tortoises, 402
Solasteridæ, 109
Solen, 251, 253
Solenidæ, 248, 251, 253
Solidungula, 522, 525
Soldier-crabs, 213
Soldier-termites, 174
Solitaire, 461
Somatic cavity, 55, 76, 133, 302
Somite, 133, 150
Sorex, 552
Soricidæ, 552
Southern Whale, 506
Spatangidæ, 108
Spatularia, 365
Specialisation of function, 13, 14
Species, 24
Spermaceti Whales, 507
Sperm-Whales, 507

Sphargis, 403
Spheniscidæ, 453, 455
Spicula, 42
Spider-Crabs, 214
Spider-Monkeys, 565
Spiders, 191, 192
Spinal cord, 325
Spinal elements of skeleton, 307
Spinnerets, 164, 176, 191
Spiracles, 147, 160, 358, 363, 504
Spirifer, 240
Spiriferidæ, 240
Spirula, 282, 293
Spirulidæ, 293
Spongida, 31, 41 ; reproduction of, 45
Spontaneous generation, 46
Spoon-worms, 136
Spores, 5, 45
Spring-tails, 168
Squamata (*Reptilia*), 391 ; (*Edentata*), 498
Squids, 275
Squilla, 195, 204
Squirrels, 550
Stag, 519
Stalk-eyed *Crustacea*, 204
Star Corals, 83
Star Fishes, 98, 111
Starlings, 464
Statoblasts, 223
Steneosaurus, 421
Stentor, 51, 52.
Sternum of *Crustacea*, 205 ; of *Chelonia*, 400 ; of *Aves*, 433 ; of *Mammalia*, 471
Stephanoceros, 130
Stigmata, 141, 147, 160, 185
Sting (of *Hymenoptera*), 178
Stoat, 544
Stolons, 230, 231
Stomapoda, 195, 204
Stomatous Protozoa, 31
Storks, 456
Strepsiptera, 157, 180
Strepsirhina, 563
Strigidæ, 466
Strobila, 73, 123, 124
Struthio, 458
Struthionidæ, 457
Sturgeon, 332, 361, 365
Sturionide, 365
Sturnidæ, 464
Stylops, 180
Sub-brachiata, 366
Sub-kingdoms, 24
Suctoria, 51, 139
Sun-animalcule, 38
Sun-stars, 109, 111
Suidæ, 511
Supra-œsophageal ganglion, 211, 217
Surinam Toads, 386
Sus, 512
Suspecta (*Ophidia*), 407, 409
Sutures, 297, 393, 473
Swallows, 465
Sweet-bread, 317
Swifts, 465
Swimming-bladder of Fishes, 344
Swimmerets, 206
Swine, 511
Sylviadæ, 464
Symmetry of animal forms, 22
Sympathetic nervous system, 302, 325
Syngnathidæ, 367
Syrinx, 136

TABLE of Classification, 28
Tabulæ, 81
Tachypetes, 455
Tænia, 118, 125
Tæniada, 118 ; development of, 122
Talitrus, 195, 204
Talpa, 552
Talpidæ, 551
Tantalinæ, 456
Tape-worm, 118
Tapirs, 524
Tapiridæ, 521, 524

Tardigrada, 188
Tarsus, 156, 315
Tasmanian Devils, 492
Taxonomy, 10, 11
Tectibranchiata, 264
Teeth, 474
Tegenaria, 192
Teguexin, 413
Teius, 413
Teleosaurus, 421
Teleostei, 349, 365
Telson, 202, 207
Tentacles of *Cœlenterata*, 58; *Polyzoa*, 221; *Tunicata*, 226; *Cephalopoda*, 276
Tenuirostres, 464
Terebella, 143
Terebra, 178
Terebratula, 238
Terebratulidæ, 238
Teredo, 251, 253
Tergum, 205
Terricola. (See *Oligochæta*.)
Termites, 173
Termitidæ, 172
Test, (of *Echinus*), 99; (of *Tunicata*, 226, 230
Testudinidæ, 402
Testudo, 402
Tetrabranchiata, 289, 293
Tetrao, 460
Tetraonidæ, 460
Teuthidæ, 292
Thalassarctos, 540
Theca, 81
Thecosomata, 272
Thorax, 150
Thornheaded worm, 127, 128
Thread-cells. (See *Cnidæ*.)
Thread-worms, 127
Thrushes, 464
Thysanura, 168
Tibia, 156, 315
Ticks, 188
Tiger, 542
Tinea, 177
Tipula, 175
Toads, 386
Tongue of *Gasteropoda*, 258
Toothshells, 264
Top-shells, 264
Torpedo, 347
Tortoises, 402
Tortricina, 177
Tortrix, 408
Toucans, 462
Tracheæ, 147, 160, 161
Trachearia, 187
Transverse processes of vertebræ, 309
Trap-door Spiders, 192
Tree Frogs, 386
Tree Pigeons, 460
Trematoda, 125
Trembley's experiments, 60
Trepangs, 115
Treronidæ, 460
Trichecidæ, 537
Trichecus, 537
Trichina, 128
Tridacnidæ, 253
Trilobita, 200
Trionychoidea, 402
Tritons, 384, 385
Tritonidæ, 384, 385
Trochilidæ, 464
Troglodytes, 567
Trophosome, 66
Trunk-fishes, 367
Tubicola, 139, 142
Tubipora musica, 82, 90
Tubiporidæ, 90
Tubularia, 67
Tunic, 225, 226
Tunicata, 218, 225; reproduction of, 230; general characters of, 226; nervous system of, 230; classification of, 230; summary of structure of, 233
Turbellaria, 126
Turbinidæ, 264
Turkeys, 460

Turrilites, 297
Turtles, 402
Types, morphological, 14, 17
Typhlopidæ, 412

Ulna, 315
Umbo, 243
Umbrella-disc, 71
Unau, 496
Uncinate process, 433
Ungulata, 510
Unionidæ, 253
Univalve shell, 241, 254
Upupidæ, 464
Uraster, 111
Urea, 324
Ureters, 325
Urodela, 381, 382
Uropygium, 429
Ursidæ, 539
Ursus, 540

VACUOLES, 36, 49
Vaginicola, 51, 52
Valves of heart, 322, 323
Valves of shell, 234, 243, 244
Varanidæ, 413
Varieties (of species), 25
Vegetative life, functions of, 326
Vegetative repetition of parts, 133
Veins, 322, 323
Velella, 69, 70
Velum, 71, 271
Venenosa, 410
Ventral fins, 336
Ventral oar, 137
Venus' girdle, 93, 95
Vertebra, 307
Vertebra, ideal typical, 309
Vertebrata, 20, 300; characters of, 300; limbs of, 304, 314; jaws of, 305; endoskeleton of, 305; exoskeleton of, 306; digestive system of, 315; salivary glands of, 316; absorbent system of, 317; respiratory system of, 324; nervous system of, 325; reproduction of, 326; blood-corpuscles of, 318; hæmal system of, 320; classification of, 327, 571
Vespidæ, 178
Vespertilio, 557
Vespertilionidæ, 557
Vibracula, 222
Viperidæ, 408
Viperina, 406, 408
Vipers, 408
Virgularia, 90
Visceral clefts, 304
Visceral tube of Vertebrata, 302
Viverra, 543
Viverridæ, 542
Viviparous reproduction, 327
Von Baër's law, 32, 33, 303
Vorticella, 50, 51
Vulpes, 541
Vultures, 466
Vulturidæ, 466

WALDHEIMIA, 238
Walrus, 537
Warblers, 464
Wasps, 178
Water-beetle, 181
Water-boatman, 170
Water-bugs, 170
Water-fleas, 198
Water-newts, 384
Water-snakes, 410
Water-spider, 193
Water-vascular system. (*See* Ambulacral system.)
Weasels, 543, 544
Whalebone, 502, 503
Whales, 501, 502, 506
Whales' food, 271, 503
Wheel animalcules, 98, 129
Whelks, 264
White ants, 172, 173
Whorls of shell, 255

Wild Boar, 512
Wings of Insecta, 156
Wolverine, 541
Wolves, 541
Wombat, 492
Wood-louse, 203
Woodpeckers, 440, 462
Wrasse, 367
Wrist, 315

XIPHOSURA, 201

ZEBRA, 526
Zeuglodon, 509
Zoantharia, 78; *Malacodermata*, 78; *sclerodermata*, 79; sclerobasica, 87
Zoanthidæ, 78, 79
Zoea, 212
Zonal symmetry, 22
Zoöid, 65, 232
Zoology, definition of, 2
Zootoca, 412
Zygapophyses, 309

THE END.

Printed by R. & R. CLARK, *Edinburgh*.